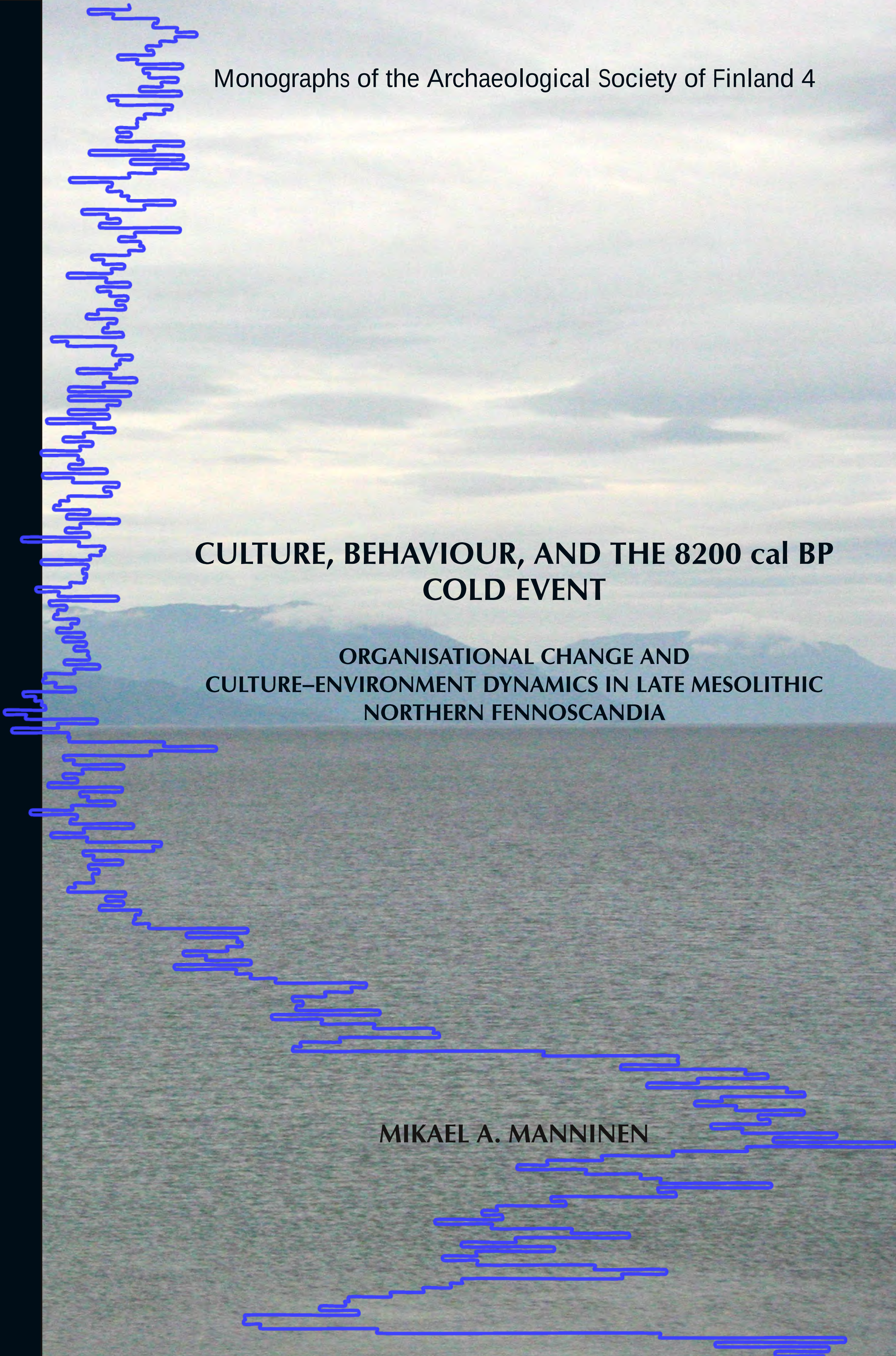

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CULTURE, BEHAVIOUR, AND THE 8200 cal BP COLD EVENT

ORGANISATIONAL CHANGE AND CULTURE–ENVIRONMENT DYNAMICS IN LATE MESOLITHIC NORTHERN FENNOSCANDIA

MIKAEL A. MANNINEN

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Academic dissertation to be publicly discussed, by due permission of the Faculty of Arts at the University of Helsinki in auditorium XII, on the 25th of January, 2014 at 12 o'clock.

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ABSTRACT

This dissertation focuses on Late Mesolithic (*ca*. 8450–6850 cal BP) lithic technological changes in the northernmost parts of Finland, Norway, and Sweden and on the relationship between these changes and the 8.2 ka climate event that was caused by a disruption in the North Atlantic Thermohaline circulation. The study uses a framework derived from Darwinian evolutionary theory and acknowledges the effects of both environmental constraints and socially transmitted information, i.e., culture, in the way lithic technology was organised in the studied region. The study discusses whether climatic cooling and its effects on the biotic environment could explain the way lithic technology and settlement patterns were reorganised during the Late Mesolithic.

The dissertation takes an organisational approach to the study of past cultural change and seeks to understand changes in prehistoric material culture by studying lithic technology and settlement configuration using lithic technological, statistical, and spatial analyses. The results suggest that Late Mesolithic coastal communities were affected by a marked decrease in marine productivity that resulted from the cooling caused by the 8.2 ka event and a subsequent cold episode at *ca*. 7700 cal BP. It is concluded that the technological changes that occurred during the marine cooling were a result of developments that led to increased use of terrestrial resources and an accompanying long-distance coast/inland residential mobility pattern.

The study contributes to a wider field of research into past climate change as a factor in prehistoric ecological, cultural, and behavioural change and provides reference material for studies on the impacts of future climate change on human communities. The results suggest that in northernmost Fennoscandia, the marine ecosystem is particularly sensitive to disturbances in the North Atlantic oceanographic system. In addition, the study provides new knowledge concerning the relationships between raw material availability, lithic technology, and culture. This new knowledge is widely applicable in research on the way lithic technology was organised in relation to other behavioural and organisational dimensions in past human adaptations.

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THE THESIS IS BASED ON THE FOLLOWING FIVE PAPERS REFERRED TO IN THE TEXT BY THEIR ROMAN NUMERALS:

I Manninen, M. A. & Knutsson, K. 2011. Northern Inland Oblique Point Sites – a New Look into the Late Mesolithic Oblique Point Tradition in Eastern Fennoscandia. In: T. Rankama (Ed.), *Mesolithic Interfaces – Variability in Lithic Technologies in Eastern Fennoscandia*. Monographs of the Archaeological Society of Finland 1, 143–175. http://www.sarks.fi/masf/masf_1/masf_1.html

II Manninen, M. A. 2009. Evidence of mobility between the coast and the inland region in the Mesolithic of Northern Fennoscandia. In: S. B. McCartan, R. Schulting, G. Warren & P. Woodman (Eds.), *Mesolithic Horizons*, Vol. I. Oxbow books, Oxford, 102–108.

III Tallavaara, M., Manninen, M. A., Hertell, E. & Rankama, T. 2010. How flakes shatter: a critical evaluation of quartz fracture analysis. *Journal of Archaeological Science* 37, 2442–2448. doi:10.1016/j.jas.2010.05.005

IV Manninen, M. A. & Tallavaara, M. 2011. Descent History of Mesolithic Oblique Points in Eastern Fennoscandia – a Technological Comparison Between Two Artefact Populations. In: T. Rankama (Ed.), *Mesolithic Interfaces – Variability in Lithic Technologies in Eastern Fennoscandia*. Monographs of the Archaeological Society of Finland 1, 177–211. http://www.sarks.fi/masf/masf_1/masf_1.html

V Manninen, M. A. & Knutsson, K. 2014. Lithic raw material diversification as an adaptive strategy—Technology, mobility, and site structure in Late Mesolithic northernmost Europe. *Journal of Anthropological Archaeology* 33, 84–98. doi:10.1016/j.jaa.2013.12.001

AUTHOR'S CONTRIBUTION TO THE PAPERS:

I The study was planned, the data were collected, and the archive and literature survey was conducted jointly by both authors. K. Knutsson was responsible for 60% of the lithic analyses and M. A. Manninen for 40%. The other analyses were conducted jointly by both authors. M. A. Manninen wrote the paper with contributions from K. Knutsson.

III The study was planned and the experiments conducted jointly by all authors. The statistical analyses were conducted, the data prepared, and the paper was written by M. Tallavaara with contributions from the other authors in the order indicated by the author list.

IV The study was planned and written by M. A. Manninen with contributions from M. Tallavaara. The data were gathered and the lithic analyses conducted jointly by both authors. The statistical analyses were conducted 60% by M. Tallavaara and 40% by M. A. Manninen. The other analyses were conducted by M. A. Manninen with contributions from M. Tallavaara.

V The study was planned by M. A. Manninen. The lithic data were collected by K. Knutsson (60%) and M. A. Manninen (40%). M. A. Manninen conducted all analyses except for the lithic technological classification, of which K. Knutsson conducted 60% and Manninen 40%. M. A. Manninen interpreted the data and wrote the paper with contributions from K. Knutsson.

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1. INTRODUCTION

The relationship between culture and environment is one of the long-standing themes in studies of prehistoric and present-day hunter–gatherers. The challenges posed by the physical environment in particular and the cultural responses to these challenges were recognised early on and have been recurrent topics in research in this field for decades (e.g., Binford 1973; 2001; Kelly 1995; Mauss 1905; Panter-Brick *et al.* 2001; Pälsi 1916; Siiriäinen 1981a; Steward 1955).

During the last few decades, approaches that relate cultural variability to environmental factors by uniting ecological and evolutionary perspectives have gained a footing in studies of hunter–gatherer culture–environment dynamics (e.g., Binford 2001; Broughton & Cannon 2010a; Kelly 1995; Surovell 2009). In tandem with this trend and with the introduction of high-resolution climate reconstructions from a wide array of biological and physical proxy records, the impact of past climate change as an explanatory factor in prehistoric cultural and behavioural change has also (re)gained importance (e.g., Bonsall *et al.* 2002; Boyd & Richerson 2005; Eren 2012a; Hald 2009; McClure *et al.* 2009; Munoz *et al.* 2010; Riede 2009a; Schmidt *et al.* 2012; van Andel *et al.* 2003; Williams *et al.* 2010). The present study contributes to this discussion.

1.1. A Late Mesolithic change in northern Fennoscandian lithic technology

This dissertation focuses on changes in stone tool production technology that took place in parts of northern Europe during the Late Mesolithic (*ca.* 6500–4900 cal BC or 8450–6850 cal BP). During most of the Mesolithic period, a regional difference existed in stone tool production technology between the Barents Sea coastal sphere in present-day northeastern Norway, that is, the Finnmark coast (Fig. 1), and the adjacent inland areas in present-day Finland and Norway (Grydeland 2005; Hood 2012; Kankaanpää & Rankama 2005; Olsen 1994; Woodman 1999; Papers I and V). However, roughly coinciding with the introduction of a

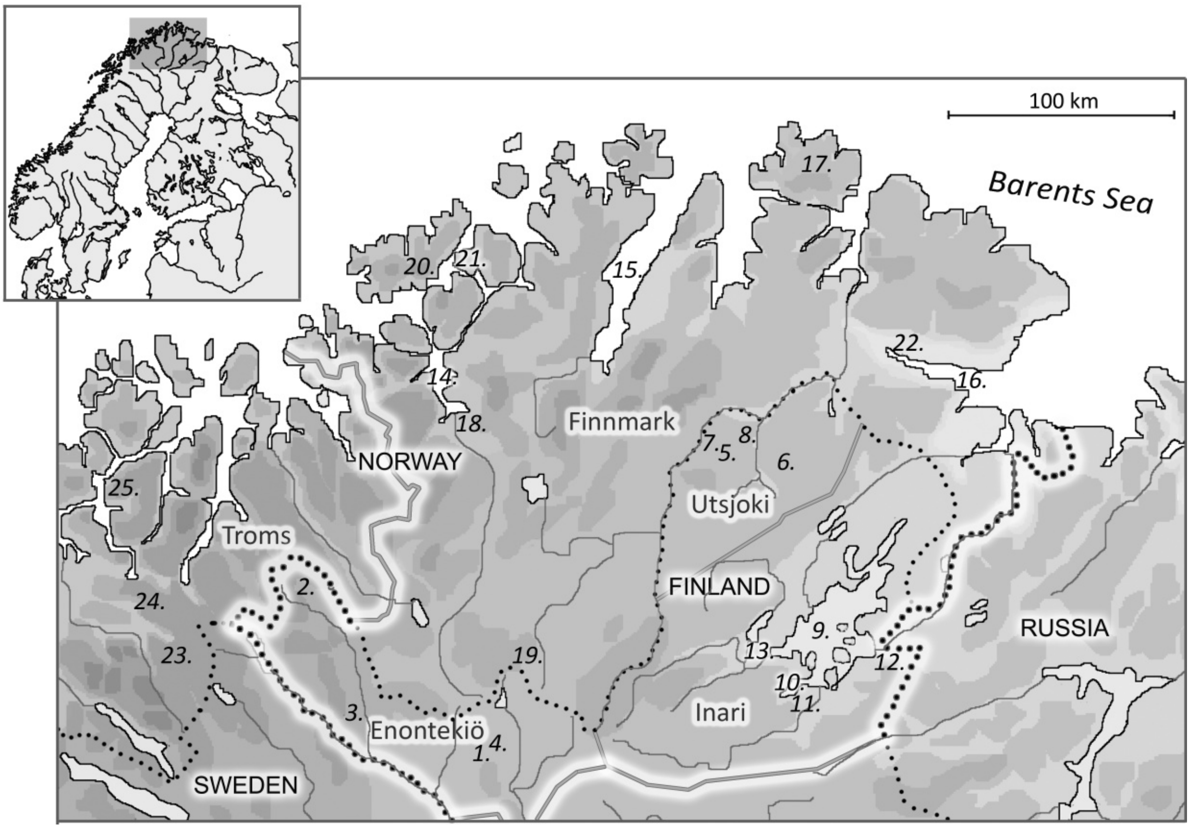
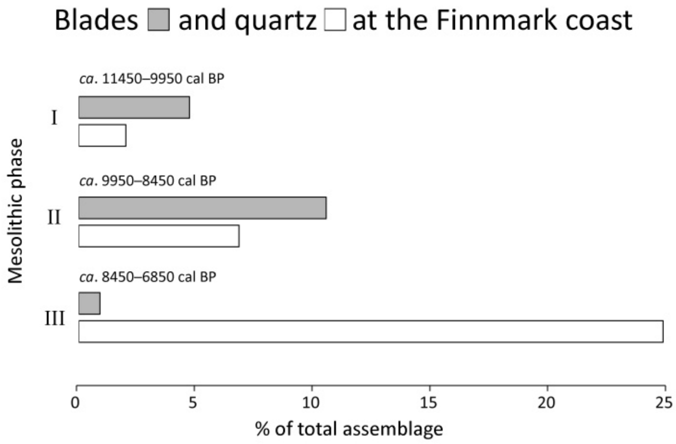


FIGURE 1. Northernmost Fennoscandia and the central study area (white outline), consisting of the county of Finnmark in Norway and the municipalities of Utsjoki, Inari, and Enontekiö in Finland. Important locations and sites mentioned in the text: 1. Ounasjärvi; 2. Toskaljavri; 3. Tsuolbmajavri; 4. Museotontti; 5. Baišduottar/Paistunturit; 6. Sujala; 7. Mávdnaávži 2; 8. Jomppalanjärvi W; 9. Lake Inari; 10. Lake Rahajärvi; 11. Kaunisniemi 3; 12. Nellimjoen suu S; 13. Vuopaja; 14. Altafjord; 15. Porsangerfjord 16. Varangerfjord; 17. Nordkinnhalvøya; 18. Alta; 19. Aksujavri; 20. Slettnes; 21. Melkøya; 22. Mortensnes: 23. Devdis I; 24. Almenningen 1; 25. Skarpeneset. Elevations above sea level are indicated by 100-metre contour intervals. Map by the author.

new point type, namely the margin-retouched "transverse point"[1], and a consequent spread of the margin-retouched point concept, there were marked changes in material culture in the whole region, the most notable of which is the way the new point type was put to use in both coastal and inland settings and in areas in eastern Fennoscandia from where immediately preceding lithic projectile point types are not known.

On the Finnmark coast, the Late Mesolithic period also saw the end of the production of formal blades, as well as changes in raw material economy—above all, an increased use of vein quartz (**Fig. 2**; Grydeland 2000; 2005:57; Hesjedal *et al.* 1996:159; Schanche 1988:124)—while in the inland region, non-local raw materials are recurrently found in association with margin-retouched points up to 150 kilometres from their coastal sources (**Fig. 3**; Havas 1999; Hood 2012; Manninen 2005; 2006; Nordqvist & Seitsonen 2009; Papers I, II, IV, and V). Although not discussed in more detail in this study, it is worth noting that in the northwestern part of the Norwegian

1 In much of the literature discussing the Late Mesolithic margin-retouched points in northernmost Fennoscandia, these points are called transverse or oblique points to distinguish them from earlier margin-retouched points called tanged single- or double-edged tanged points, even if the shapes of the points is very varied throughout the millennia (Paper I; IV). In this dissertation, the terminology used is defined in the individual papers. It should be noted, however, that in Paper II, the term oblique point is used for Late Mesolithic margin-retouched points, while in Papers I and IV, as well as in this introductory chapter, the term encompasses all Mesolithic margin-retouched points in northern and eastern Fennoscandia, regardless of edge shape or date.



FIGURES 2&3. Left: the relative amounts of blades and quartz in the combined lithic assemblages from three multi-period sites on the Finnmark coast. Data from Hesjedal *et al*. (2009 Melkøya), Hesjedal et al. (1996, Slettnes), and Schanche (1988, Mortensnes). Right: Late Mesolithic margin-retouched points of varying edge shapes from Utsjoki and Inari, Finland. All were made of varieties of non-local (coastal) chert. Modified from Paper IV: Fig. 1. National Museum of Finland. Photograph by M. A. Manninen.

Atlantic coast, there are contemporaneous but differing changes indicated by a shift in blade production technology (Hagen 2011:63–67).

Significantly, a range of contemporaneous changes has also been detected in the archaeological record in many other parts of Europe, North Africa, and the Near East, while there is growing evidence that many of these changes were the result of environmental stress induced by climatic change, or more specifically, the 8200 cal BP cold event (e.g., Budja 2007; Edinborough 2009; Fernández López de Pablo & Jochim 2010; González-Sampáriz *et al.* 2009; Mercuri *et al*. 2011; Robinson *et al.* 2013; Weninger *et al.* 2006). In this dissertation, I study whether and how the above-described changes in lithic technology in northernmost Fennoscandia, and especially the changes in the way technology was organised, could be related to the abrupt climate change.

1.2. The study area

The main area under study in this dissertation covers northernmost Finnish Lapland and the county of Finnmark in Norway. The area is located in a region in which the marine environment in particular can be expected to be directly affected by the sorts of disruptions in North Atlantic oceanic circulation that are considered to be the main causes of most of the abrupt climatic events that occurred in the early Holocene (e.g., Clark *et al.* 2001; Renssen *et al.* 2002).

Depending on the level of analysis and the specific question under discussion, in the individual papers, the geographic focus is at times expanded to include northern Sweden and the county of Troms in Norway (Papers I and V), the more southerly parts of Finland (Papers I and IV) and occasionally even the whole of northern Europe (Paper IV).

1.3. History of research and chronology—a short overview

The area consisting of northern Finnish Lapland and Finnmark is traditionally divided into coastal and inland regions in archaeological research. The border between these regions is, however, in many ways unclear and at least in part follows the present-day national and political border between

FIGURE 4. A sequence of raised shorelines in Roddines, Porsangerfjord. Photograph by the author.

Finland and Norway (*cf.* Havas 1999; Hood 2012; Rankama 1995; 2003). There are nonetheless also differences in the physical environment, such as differences in topography, geology, and habitat distribution, which roughly coincide with the national border. In terms of lithic technology, the most notable difference is in the availability of raw materials: sources of fine-grained lithic material of good workability are found almost exclusively in the area of present-day Norway (see chapter 1.6.1). Together with the national border, these environmental differences, in addition to affecting human adaptations, have contributed to the fact that the Barents Sea coastal strip has in many instances been treated as a detached entity, and therefore, two separate archaeological research traditions, as well as asynchronous chronological frame-works, have long co-existed in the area (Hood 2012; Rankama 1995; 2003; Paper I).

Recently, this divide has started to break down, and prehistoric phenomena are increasingly being studied within the same chronological framework and cutting across the traditional coast/inland division (e.g., Grydeland 2005; Hagen 2011; Halinen 2005; Havas 1999; Hood 2012; Knutsson 2005; Manninen 2005; 2006; Rankama 2003; Rankama & Kankaanpää 2011; Skandfer 2003; 2005). As might have been expected, the widened perspective has revealed changing patterns of land use and coast–inland contacts throughout prehistory, although there still remain clear differences between the areas.

Findings from excavated Mesolithic sites in northern Finnish Lapland suggest that the amount of fine-grained coastal lithic raw material moving into the inland region varied through the millennia, even if, for most time periods, only occasional artefacts have been found (Grydeland 2005; Havas 1999; Hood 2012; Kankaanpää & Rankama 2005; Rankama 1996). Blade production has been detected at only one site in the inland region, where also tools made on blades are rare and mostly undiagnostic flake-based technologies prevailed (Hood 2012; Kankaanpää & Rankama 2005; Manninen & Hertell 2011; Rankama & Kankaanpää 2011). At the same time, typo-chronological sequences constructed using coastal assemblages indicate that blades and blade tools were common in the coastal sphere during the first two phases of the Mesolithic (Hesjedal *et al.* 1996; Olsen 1994; Woodman 1999).

Due to the lack of chronologically diagnostic types at most of the Mesolithic inland sites, in this study, I use a timeline based on the coastal North Norwegian typo-chronologies (Hesjedal *et al.* 1996; Olsen 1994; Woodman 1993; 1999) in which the Mesolithic Stone Age is divided into three phases:

Phase I: *ca*. 11450–9950 cal BP
(*ca*. 9500–8000 cal BC or 10000–9000 BP)

Phase II: *ca*. 9950–8450 cal BP
(*ca*. 8000–6500 cal BC or 9000–7500 BP)

Phase III: *ca*. 8450–6850 cal BP
(*ca*. 6500–4900 cal BC or 7500–6000 BP)

The last of these phases I refer to as the Late Mesolithic. The advantage of a chronological framework based on coastal assemblages is the fact that it can be backed not only by using radiocarbon dated contexts but also by sequences of find locations datable by shore displacement chronology. The isostatic rebound that started after the Scandinavian Ice Sheet retreated from the area (**Fig. 4**) offers the possibility to shoreline date sites and is the reason why the earliest Mesolithic sites at the seashore can be located nearly 100 metres above the current sea level (Bøe & Nummedal 1936; Grydeland 2000; Møller 1987; Tanner 1935). In the study area, where the preservation of organic material is poor, and where, especially before AMS-dating became widely available, the possibilities for radiocarbon dating have been scarce, shore displacement chronology has offered, and still offers, possibilities for detecting typologically and technologically differing phases. However, when studying human activity, shore displacement chronology can in most cases only give *post quem* dates (*cf.* Matiskainen 1982). Therefore, in this dissertation, I use shoreline dates only when needed to supplement the relatively scarce radiocarbon date dataset.

For these reasons, i.e., the nature of shoreline dates and the scarcity of radiocarbon dates, the chronological boundaries in the three-partite chronological division of the Mesolithic in the region are not well established and do not account for regional differences, of which there are many indications (e.g., Carpelan 2003; Grydeland 2005; Hagen 2011; Halinen 2005; Hood 2012; Rankama & Kankaanpää 2011; Skandfer 2005; Paper I). However, using the above-mentioned typo-chronological studies and some of the more recent research (Hagen 2011; Grydeland 2000; 2005; Hesjedal *et al.* 2009; Hood 2012; Kankaanpää & Rankama 2005; Rankama & Kankaanpää 2011; Skandfer 2003), a rough typo-chronological sequence of tools and technology used in the area during the Mesolithic can nevertheless be presented (**Fig. 5**).

This scheme includes the conjecture that simple margin-retouched arrow-

		Phase I *ca* . 11450–9950 cal BP	Phase II *ca* . 9950–8450 cal BP	Phase III *ca* . 8450–6850 cal BP
Raw material	*Coast*	Chert/quartzite + minor use of quartz	Chert/quartzite + minor use of quartz	Decrease in chert/quartzite + clear increase in quartz
	Inland	WMS (1 late site)	Quartz + rare artifacts of coastal chert/quartzite	Mainly quartz, but also production from coastal chert/quartzite
Primary production	*Coast*	Blades & flakes	Blades & flakes	Flakes in East-Finnmark, flakes + bladelets in Troms
	Inland	Blades (1 late site)	Flakes	Flakes
Arrowheads	*Coast*	Margin-retouched	Margin-retouched in Troms and probably Finnmark	Margin-retouched
	Inland	Tanged post-Swiderian	Lack of arrowheads	

wms = weakly metamorphosed sandstone

FIGURE 5. Typo-chronological division of lithic technological trends during the three Mesolithic phases in the study area, based on studies by Hesjedal *et al*. (1996), Hood (2012), Olsen (1994), Rankama & Kankaanpää (2011), and Woodman (1993).

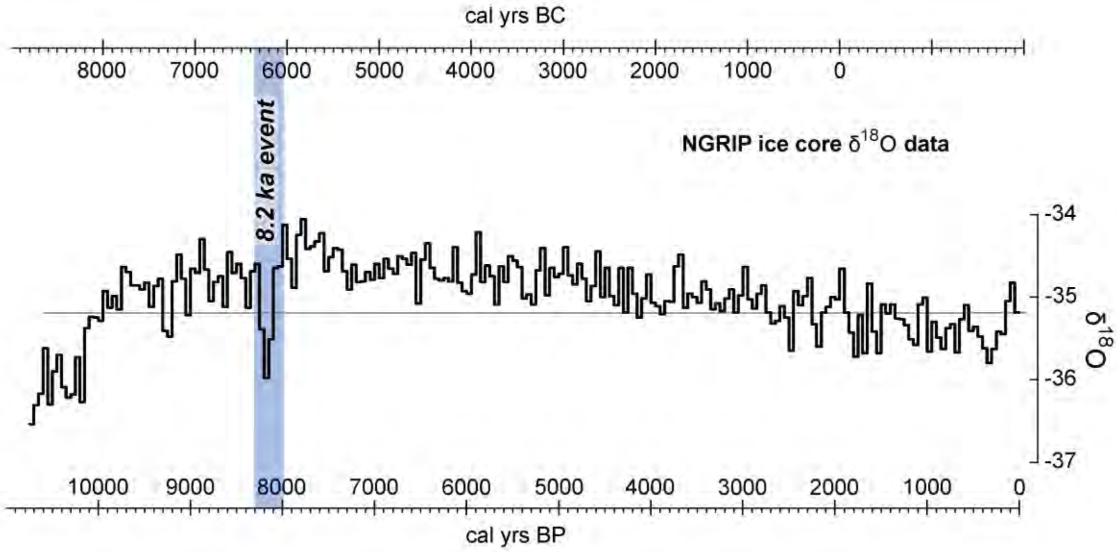


FIGURE 6. North Greenland Ice Core Project Oxygen Isotope Data (NGRIP 2004).

heads were in use at Barents Sea coastal sites throughout the Mesolithic (Odner 1966; Olsen 1994:31, 39). This view was challenged by Hesjedal *et al.* (1996:184–185, 198) who suggested that the use of margin-retouched points ended at the beginning of Phase II and restarted during Phase III. This suggestion was based on the lack of corresponding finds assigned to the intervening period. The absence of margin-retouched points during Phase II may, however, be largely explained by a record gap affecting coastal sites (Paper I) and the fact that the typo-chronological definition of Phase II seems to be largely based on assemblages representing technology associated with a colonisation wave of eastern "post-Swiderian" hunter–gatherers into the area (Rankama & Kankaanpää 2011; Sørensen *et al*. 2013). Finds of margin-retouched points radiocarbon dated to Phase II in recent excavations at Skarpeneset (Tønsnes, Troms County) indicate that such points were present, if not in northeastern Finnmark, at least in its close vicinity, during Phase II (Henriksen 2010; Nilsen & Skandfer 2010).

Only a few studies have explicitly addressed the changes in lithic technology that happened in the area during the Late Mesolithic. Rankama (2003) discussed the increase in quartz use together with the change in blank production and suggested that this could indicate a colonisation of the Finnmark coast by quartz-adapted groups that originated in the inland region, while Grydeland (2005) explained the same change by increased cooperation between coastal and inland groups. Knutsson (2005) related the increased archaeological visibility of margin-retouched points in the area during Phase III (in comparison to Phase II) to a cultural reproduction of the past as a response to a time of crisis. Finally, Hagen (2011) has recently reviewed earlier research on the interface between Phases II and III in the region and discussed how technological changes and trends observed in these studies could be related to environmental factors, most notably the 8200 cal BP climate event.

A substantial amount of research literature also exists in which questions related to the Late Mesolithic changes in the area are discussed and notes on such topics as the origin and chronological position of oblique points in Finland, northern Sweden, and northern Norway are made. However, as this literature is addressed in the individual papers (I, II, IV, and V), it is not discussed in detail here.

1.4. The 8200 cal BP cold event

In general, the early part of the Holocene (before *ca*. 8000 cal BP) was characterised by substantial climatic fluctuation and environmental change, including several abrupt cooling episodes, the effects of which are detectable in multiple proxy records around the Northern Hemisphere (e.g., Blockley *et al.* 2012; Bond *et al.* 1997; Mayewski *et al.* 2004). The most prominent and widely studied of the Holocene cold events is the 8200 cal BP event (henceforth the 8.2 ka event), an abrupt climate change which is clearly detectable in, for example, the high-resolution North Greenland ice core oxygen isotope data as being the strongest climatic signal of the Holocene (**Fig**. **6**).

The event is tought to have been initiated by the final drainage of the pro-glacial lakes Ojibwa and Agassiz into the North Atlantic as a part of the Laurentide Ice Sheet collapse in North America (e.g., Barber *et al.* 1999; Clark *et al.* 2001; Törnqvist & Hijma 2012; Wiersma & Jongma 2010). The fresh-water pulse caused a disruption in the Atlantic Meridional Overturning Circulation, which in itself plays a critical role in the world's climate system (e.g., Alley & Ágústsdóttir 2005; Barber *et al.* 1999; Seppä *et al.* 2007; Wiersma & Renssen 2006). To put the magnitude of the event into perspective, it should be noted that the 8.2 ka event is used as a "worst case scenario" in modelling the effects of future climate change (Schwartz & Randall 2003).

The 8.2 ka event was part of a climatic cooling period spanning *ca.* 8600–8000 cal BP (Rohling & Pälike 2005; Thomas *et al.* 2007; Walker *et al.* 2012:Fig. 3) that interrupted the long-term trend of rising early-Holocene temperatures. The event "proper" lasted approximately 160 years (Daley *et al.* 2011; Kobashi *et al.* 2007). It is detected as a marked cold snap in multiple paleoclimatic records from the Greenland ice cores and a variety of sedimentary records, especially in northern Europe (e.g., Alley & Ágústsdóttir 2005; Seppä *et al.* 2007; Thomas *et al.* 2007; Walker *et al.* 2012), while the climatic changes caused by the event, most notably the cooling in the Northern Hemisphere and an increase in aridity in the lower latitudes, are thought to have affected human populations in many parts of Europe and beyond (**Fig. 7**).

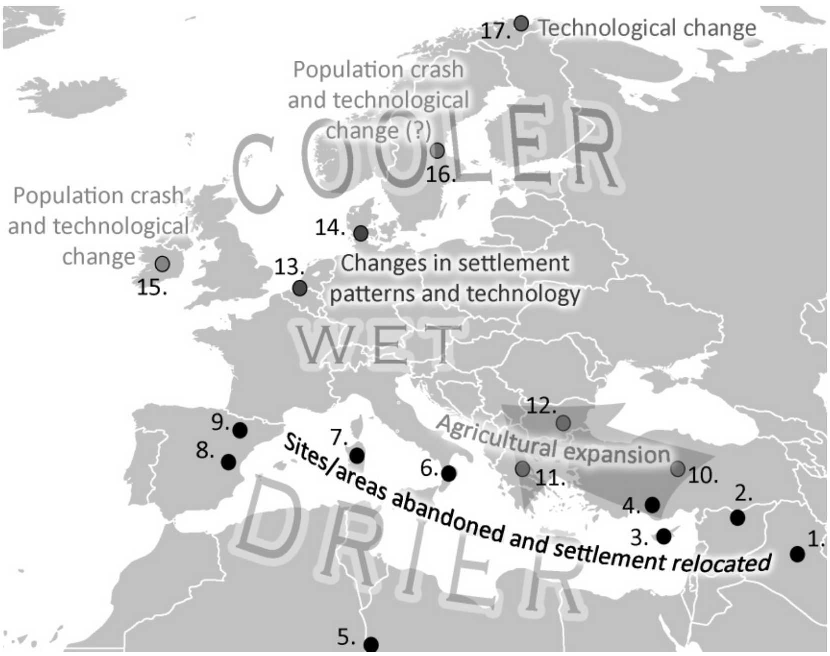


FIGURE 7. Major climatic and hydrological changes in Europe during the 8.2 ka event (Magny *et al*. 2003; Morrill & Jacobsen 2005; Seppä *et al*. 2007) and a sample of regions where the effects of these changes have been observed in the archaeological record (Staubwasser & Weiss 2006 (1.); van der Plicht *et al*. 2011 (2.); Weninger *et a*l. 2006 (3. & 4.); Mercuri *et al*. 2011 (5.); Berger & Guilaine 2009 (6. & 7.); Fernández López de Pablo & Jochim 2010 (8.); González-Sampáriz *et al*. 2009 (9.); Weninger *et al*. 2006; see also Budja 2007 (10.–12.); Robinson *et al*. 2013 (13.); Edinborough 2009 (14.); Riede 2009a (15. & 16.); Hagen 2011; Paper IV (17.)). Map by the author.

1.5. Climate events and hunter-gatherers

Because hunter–gatherers live directly off the natural environment, they are affected by all changes in their respective ecosystems, either directly or indirectly (*cf.* Binford 2001; Dincauze 2000; Kelly 1995). This also means that environmental changes can be expected to be reflected in the archaeological record in various ways that are determined by such things as the severity of the effects of the changes on the ecosystem, the readiness of any given group to adapt, and the riskiness of the group territory. Several case studies show that there are good reasons to assume that in many parts of the world, abrupt climate change has caused population instability and/or demographic collapse, as well as cultural change (e.g., Adger *et al.* 2012; Gronenborn 2009; Munoz *et al.* 2010; Pfister & Brázdil 2006; Riede 2009a; Robinson *et al.* 2013; Tallavaara *et al. in press*.).

Gronenborn (2009; following Pfister & Brázdil 2006) has conceptualised the mechanism behind such changes in communities, such as those of prehistoric hunter–gatherers, which respond on a local level to both non-human and human threats (**Fig. 8**). This generalised scheme offers insights into the catastrophic effects an abrupt climate change can have on hunter–gatherer adaptations and demography as a consequence of large-scale ecosystem turmoil. In risky environments in particular, a negative change in any key variable can lead to malnutrition, lowered fertility, and increased mortality, as well as to various behavioural responses, such as migration, conflict, and technological change. The demographic crashes caused by such crises and the following social and economic reorganisation can therefore be expected to appear as rapid changes in the archaeological record (*cf.* Riede 2009a).

In recent years, the link between climate and human population size has been studied by scrutinising the applicability of radiocarbon dates as a proxy for prehistoric demographic fluctuation (e.g., Gamble *et al.* 2004; Riede 2009a; Surovell *et al.* 2009; Tallavaara *et al.* 2010; Tallavaara & Seppä 2012; van Andel *et al.* 2003; Williams 2012). A prerequisite for such dates-as-data approaches to the study of the impact of climate on human societies is a sufficiently large taphonomically and statistically controlled sample of radiocarbon dates from the studied region (e.g., Williams 2012). This is not the case in northernmost Fennoscandia, where shore-bound sites on the Barents Sea coast from the period under study are likely to have been destroyed by the mid-Holocene Tapes transgression (Møller 1987; Paper I), as well as by the Storegga tsunami (Romundset & Bondevik 2011), and where the number of radiocarbon-dated contexts is still relatively low.

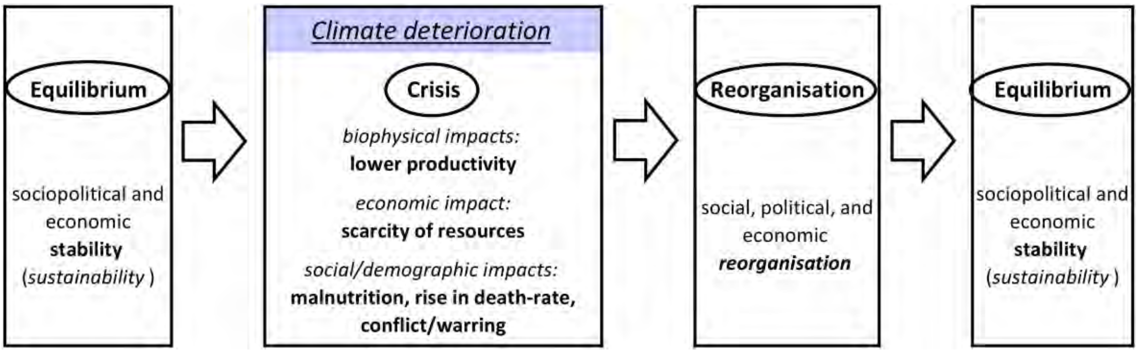


FIGURE 8. Schematic representation of the effects of climate-induced culture change (modified from Gronenborn 2009).

FIGURE 9. Examples showing the geographic and environmental diversity in the study area. Top: Barents Sea coast at Altafjord (a) and Varangerfjord (b). Middle: Inland fell area below (c) and above (d) the treeline in Baišduottar/Paistunturit, Utsjoki. Bottom: Forest shores of Lake Ounasjärvi, Enontekiö (e) and pine forest at Lake Rahajärvi, Inari (f). See Figure 1 for locations. Photographs by the author.

However, a large-scale ecosystem crisis and the economic and social reorganisation that result are likely to also cause changes in material culture and settlement configuration, not only locally but also on a regional level. Therefore, if long time periods of stability and gradual change in the archaeological record are equalled by periods of environmental equilibrium and thus with only minor fluctuation in resource availability, an abrupt large-scale climate event can be expected to cause wide-ranging changes in the archaeological record in areas where the effects of the climate change on ecosystems are severe. Assuming that the 8.2 ka event had such an impact on the environment in northernmost Fennoscandia, its effects can be expected to be visible in settlement organisation and lithic technology.

1.6. Environmental variables in the study area

The geography of the study area in Finnmark and northern Finnish Lapland is varied. The most prominent features, in addition to the Barents Sea, are the mostly barren and uneven terrain of the Barents Sea coast, the rugged fells of the Finnmark Caledonides, with deep river gorges and multiple peaks more than 900 metres high, as well as the undulating plateau to the south of the Caledonides, which is characterised by low rounded fells, lakes and rivers, as well as large areas of peatland (**Fig. 9**).

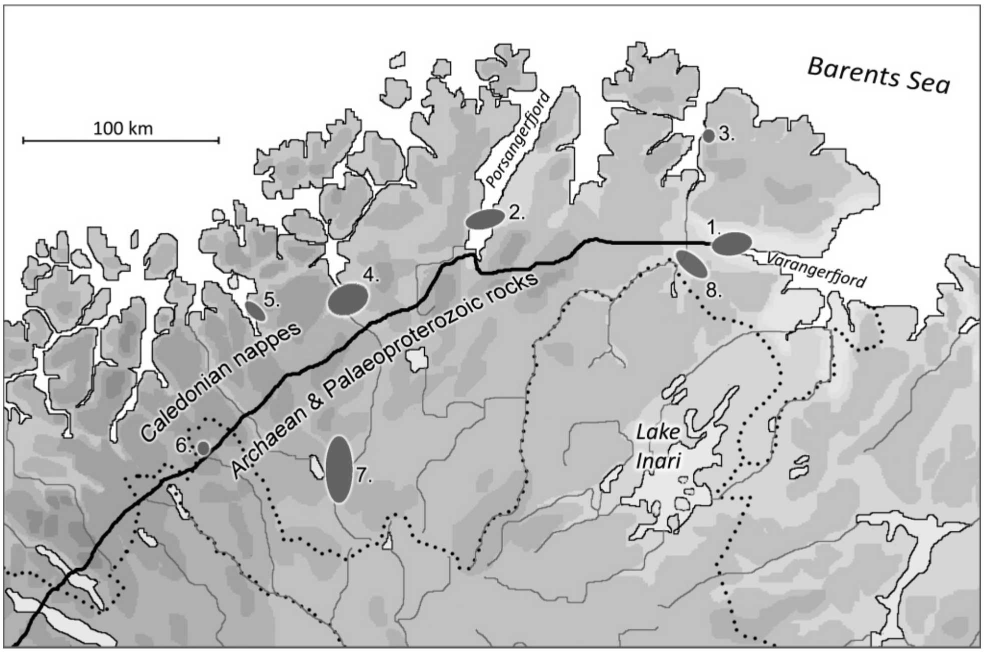


FIGURE 10. Sources of fine-grained lithic raw materials in and near the study area: 1) Chert bearing tillites; 2) Porsanger chert; 3) Oolithic chert; 4) Kvenvik chert; 5) Kvænangen chert sources; 6) Guonjarvárri chert/quartzite; 7) Possible source area for metachert/quartzite; 8) Green quartzite. 1-4), & 7) after Hood (1992b), 5) after Stensrud (2007); 6) after Halinen 2005; 8) after Kleppe (n.d.). The black line marks the geological boundary between the Archaean and Palaeoproterozoic bedrock of the Fennoscandian Shield and the younger sedimentary rocks of the Caledonian nappes (after Lehtinen *et al*. 1998). Elevations above sea level are indicated by 100-metre contour intervals. Map by the author.

The emergence of the area from under the Scandinavian Ice Sheet started from the north, and by *ca.* 10650 cal BP (or 8700 cal BC), Finnmark and northern Finnish Lapland were free of ice (Johansson & Kujansuu 2005).

1.6.1. Availability of lithic raw materials

In Fennoscandia, the occurrence of stone tool raw materials of good flakeability and controllability is largely dictated by a geological division into areas with Archaean and Palaeo-proterozoic bedrock on the one hand and younger sedimentary rocks of the Caledonian nappes on the other (**Fig**. **10**; Papers II and V).

Hood (1992a; 1992b; n.d.) has published several sources of chert and other fine-grained raw materials in Finnmark, many of which are known to have been used in prehistory. However, the archaeological material in the area also contains cherts and other raw material types of unknown origin. For example, the sources of the weakly metamorphosed sandstones used to produce large regular blades at the Phase I Sujala site in Utsjoki remain unknown (Rankama & Kankaanpää 2011), although the same, or at least macroscopically similar, material (also known as tuffaceous chert) is found at many sites in the Varanger area (Grydeland 2000; Hood 1992b:91–93).

In a similar manner as might be the case with the Sujala material (Rankama & Kankaanpää 2011), a significant proportion of the raw materials of unknown origin are likely to have come from beach and moraine deposits on the Barents Sea coast and therefore may originally have come from bedrock sources that no longer exist. However, the coverage of archaeological surveys in the region is far from comprehensive, and new lithic raw material sources and source areas are still being found, such as the recently found Guonjarvárri quarries in Kilpisjärvi (Halinen 2005:27–28), the Kvænangen chert sources near

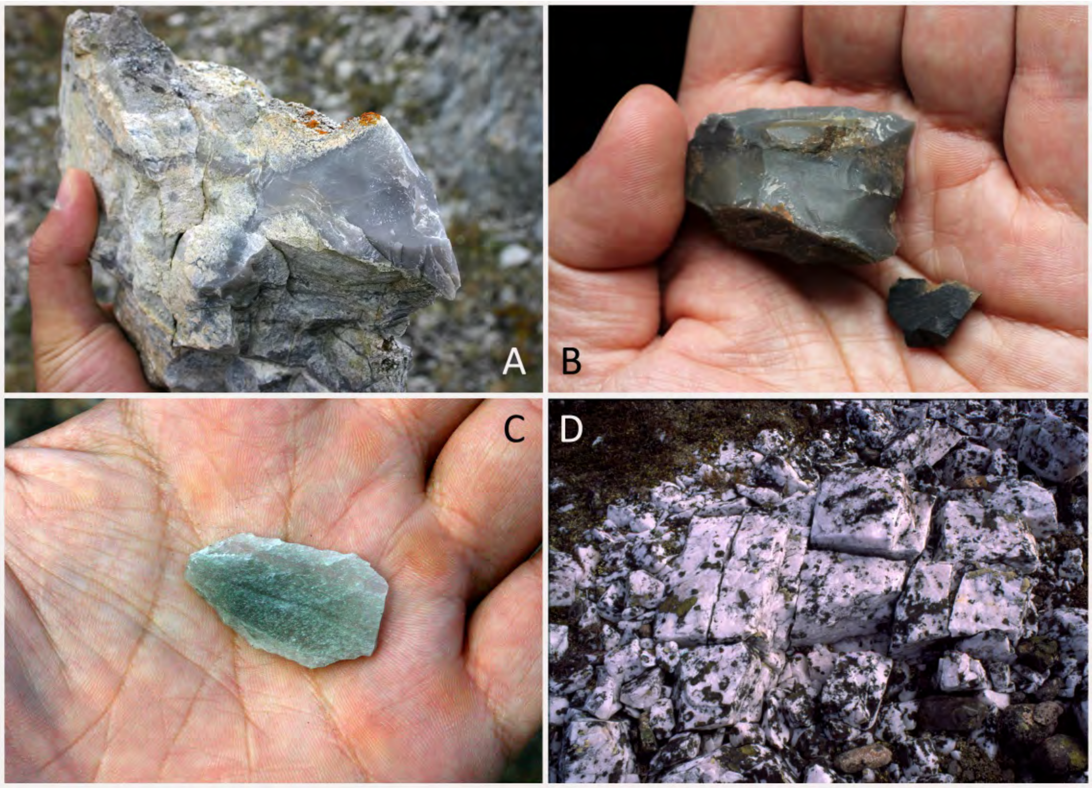


FIGURE 11. Examples of lithic raw material types available in the study area. Porsanger chert (A), Kvenvik chert (B), fine-grained green quartzite (C), vein quartz (D). Photographs by the author.

Troms (Stensrud 2007), the Melsvik chert quarry in Alta (Niemi 2012), and the Piipahta chert source near Børselvnes[2].

What is most important with respect to this study, however, is the differing availability of fine-grained raw materials within the study area (Papers II and V). Sources of raw material of good flakeability and controllability (mostly chert and fine-grained quartzite) are found only in beach and moraine deposits on the Barents Sea coast and as localised sources associated mainly with the Scandinavian Caledonides (Åhman 1967; Hood n.d., 1992a; 1992b; Rosendahl 1936). In contrast, raw materials of lower workability, especially vein quartz, are found throughout the region (**Fig. 11**).

1.6.2. The early to mid-Holocene climate

Despite regional variations, after *ca.* 10000 cal BP, the period corresponding to the Mesolithic in northernmost Fennoscandia (*ca.* 11450–6850 cal BP or 9500–4900 cal BC), was characterised by an oceanic climate that was generally warm and wet in comparison to present conditions (**Fig. 12**; Allen *et al.* 2007; Seppä & Hammarlund 2000). Paleoclimatic temperature reconstructions indicate an initially high but gradually decreasing influence of Atlantic air masses in the inland areas of northern Fennoscandia (Seppä & Hammarlund 2000), alongside a trend of rising postglacial temperatures that peaked during the Holocene Thermal Maximum (*ca.* 8000–5000 cal BP; Renssen *et al.* 2009) in both the inland region and on the Barents Sea coast (Allen *et al.* 2007; Erästö *et al. submitted*; Seppä *et al.* 2009b).

2 Piipahta is a source of Porsanger chert near Børselv/Pyssyjoki/Bissojohka that was visited by the present author in 2006. The location is marked on the topographic map by the Kven/Finnish name Piipahta, which means literally Flint Cliff. The place name Flintnes, several kilometres south along the same shore, suggests the presence of chert in other unsurveyed localities along the shores of Porsangerfjord.

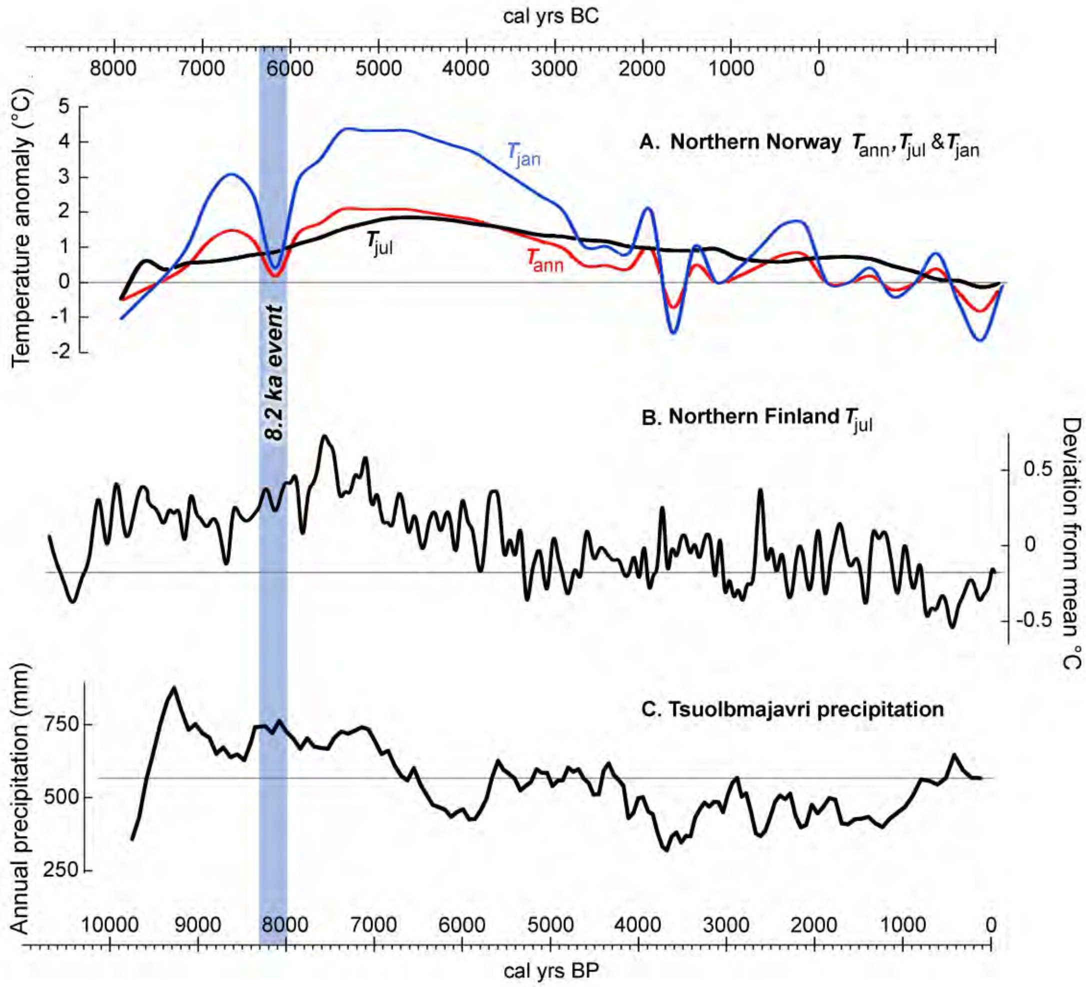


FIGURE 12. Reconstructions of Holocene temperature and precipitation. A) Northern Norway Holocene mean January (blue), mean July (black), and mean annual (red) temperatures (based on a consensus of mean July datasets, speleothem data; GISP2 Greenland Ice Core data and modern temperature relationships) presented as anomalies from modern (1961–1990) temperature (Lilleøren *et al*. 2012); B) Consensus of six mean July temperature reconstructions (based on pollen, chironomids, and diatoms) from Lakes Toskaljavri and Tsuolbmajavri in northern Finland, computed as averages of cubic spline interpolants of centred reconstructions and presented as deviation from Holocene mean temperature (Erästö *et al. submitted*); C) Annual mean precipitation (mm) inferred from Lake Tsuolbmajavri pollen assemblages (Seppä & Birks 2001; St. Amour 2009:Fig. 5-5). The grey horizontal lines indicate present conditions.

This trend, however, was punctuated by abrupt cooling episodes, most notably the 8.2 ka event (Allen *et al.* 2007; Lauritzen & Lundberg 1999; Lilleøren *et al.* 2012; Seppä *et al*. 2007; for other earlier cooling episodes, see, e.g., Balascio & Bradley 2012; Björck *et al.* 2001; Came *et al.* 2007; Fleitmann *et al.* 2008; Korhola *et al.* 2002; Lauritzen & Lundberg 1999; Rasmussen *et al.* 2007; Rosén *et al.* 2001; Seppä *et al.* 2002).

The relatively short-lived Holocene cold events vary in magnitude in the different temperature reconstructions in northern Fennoscandia, not only because of real differences in their climate effects but also due to differences and problems in the proxy records, such as varying temporal resolutions and degrees of chronological error, the time of year represented by the data (e.g., T_{jul} vs. T_{ann}), the sensitivity of the species/taxa used as biological proxies for temperature changes in a given environment, and the indirect nature of some of the climate effects (e.g., Erästö *et al. submitted*; Nyman *et al.* 2008; Rosén *et al.* 2001; Seppä *et al.* 2007; 2009b; Velle *et al.* 2010).

This is also true in case of the 8.2 ka event, which is the only prominent early Holocene cold event in the modelled mean annual and mean January temperatures for northern Norway (**Fig. 12A**). Nevertheless, this event is hardly visible in many mean July temperature reconstructions in northern Finland, even though it is detected in more southern parts of the country (Seppä *et al.* 2007; 2009b; but see Korhola *et al.* 2002) as well as in the northern Norwegian coastal area (Allen *et al.* 2007). Seppä *et al.* (2007) suggest that during the event increased cooling may have taken place mostly during the winter and early spring, and for this reason, the event is not visible in pollen-based records in northern Finland, where most of the tree taxa flower later in the year.

Based on the present evidence, it thus seems that during the 8.2 ka event, summer temperatures were not greatly affected in northernmost Fennoscandia, whereas the mean annual temperature sum decreased considerably (Allen *et al.* 2007: Fig. 5), which suggests longer and relatively colder winters.

1.6.3. The biotic environment on dry land

During and after deglaciation, the rising early Holocene temperatures brought about rapid shifts in the predominant vegetation regime in northern Fennoscandia, from open tundra vegetation, through a birch (*Betula*) forest phase, to closed forests dominated by birch and pine (*Pinus sylvestris*), especially in the inland region (Hicks & Hyvärinen 1997; Hyvärinen 1975; Rankama 1996; Seppä 1996; Seppä & Hammarlund 2000; Paper I). Accordingly, during most of the Holocene, the terrestrial environment of northernmost Fennoscandia is characterised by dynamic and fluctuating ecotones between the three recurrent types of plant communities, i.e., coniferous forest, mountain birch forest, and tundra (Allen *et al.* 2007; Seppä 1996), which form the basis of both altitudinal and latitudinal vegetation zonation.

Boreal forest reached its maximum extent in northernmost Fennoscandia between *ca.* 8300 and 4000 cal BP, with a peak prior to *ca.* 6000 cal BP when pine colonised 95% of the currently unforested areas and pine stands grew at altitudes 350–400 metres higher than they do today (Eronen *et al.* 1999; Hicks & Hyvärinen 1997; Jensen & Vorren 2008; Kultti *et al.* 2006). Peat bog formation began *ca.* 10200 cal BP at the latest (Mäkilä & Muurinen 2008). Spruce (*Picea abies*) did not arrive in the area *ca.* 4500 cal BP (Seppä *et al.* 2009a).

Currently the pine-dominated Boreal forest transitions northward into Arctic tundra over a relatively short distance (Haapasaari 1988; Seppä & Hammarlund 2000), while during the pine maximum, the distance was even shorter, with grassland and dwarf-shrub tundra present only on the Barents Sea coastal strip and in areas above the mountain birch limit, i.e., some 100 metres higher than the pine limit (Allen *et al.* 2007; Kultti *et al.* 2006).

The post-glacial spread of animal species into the area occurred roughly in tandem with the vegetation development. Reindeer (*Rangifer tarandus*) most likely arrived at the Barents Sea coast during the late glacial period, alongside a set of tundra-adapted species, while European elk (or moose, *Alces alces*) and other Boreal forest species arrived gradually in tandem with the forest development (e.g., Hakala 1997; Rankama 1996; Rankama & Ukkonen 2001). Because of the wide altitudinal and latitudinal range, the variety of biotopes has been large in the area throughout the Holocene. Therefore, most of the species that moved into the area after the last glacial cycle are still present today, and the changes in the predominant vegetation regime can be assumed to have mainly caused fluctuations in their relative abundance and ranges.

The earliest known reindeer bones in the study area are from the Sujala site in Utsjoki and date to *ca.* 10040 cal BP (Rankama & Kankaanpää 2008), while the earliest sign of elk in northern Finland (*ca.* 10030 cal BP) is from Kittilä, some 40 kilometres from the southern border of the main study area (Hildén *et al*. 2010; Sarala & Ojala 2011). From the early Holocene onwards, both species were also present in the refuse faunas of hunter–gatherer sites in the inland areas of Finnmark and northernmost Finnish Lapland (**Fig. 13**). Because of their dominance in the refuse fauna at archaeological sites (e.g., Halinen 2005; Hood 2012; Rankama & Ukkonen 2001) and their potentially high return rates (*cf.* Kelly 1995: Table 3-3; Winterhalder 1981), they can be considered the most important terrestrial species targeted by prehistoric hunter–gatherers in the area.

1.6.4. The aquatic environment

At present, the aquatic environment in the study area is characterised by a large quantity of subarctic low-productivity lakes, large river systems, and the relatively high productivity Barents Sea (Gjøsæter 2009; Rankama 1996; Sorvari 2001). The Barents Sea is a shallow shelf sea divided by the Polar Front and consisting of three main water masses, i.e., coastal, Atlantic, and arctic waters, (**Fig. 14**; Loeng 1991; Loeng & Drinkwater 2007). Warm salty Atlantic water is carried into the southern part of the sea by a branch of the Norwegian Atlantic Current (an extension of the Gulf Stream), whereas low-salinity coastal water of seasonally varying temperature is carried along the coast by the Norwegian Coastal Current (Loeng 1991). The Norwegian Atlantic Current is part of the Atlantic Meridional Overturning Circulation, which consists of a surface flow of warm water from the tropics to the North Atlantic and a southward deep-ocean transport of cold water from the North Atlantic (e.g., Schmittner *et al.* 2007). The flow of warm Atlantic water into the Barents Sea has a marked warming influence on the climate of northern Finnmark (Førland *et al.* 2009).

The Holocene history of the Barents Sea is central to the understanding of hunter–gatherer adaptations in the study area. A presence of maritime-adapted hunter–gatherers on the Barents Sea coast during the early Holocene and onwards has been shown in many studies (e.g., Bjerck 2008; Engelstad 1984; Grydeland 2000; Hesjedal *et al.* 1996; 2009; Niemi 2010; Renouf 1989). The present-day oceanographic pattern was not established in the area until *ca.* 7500

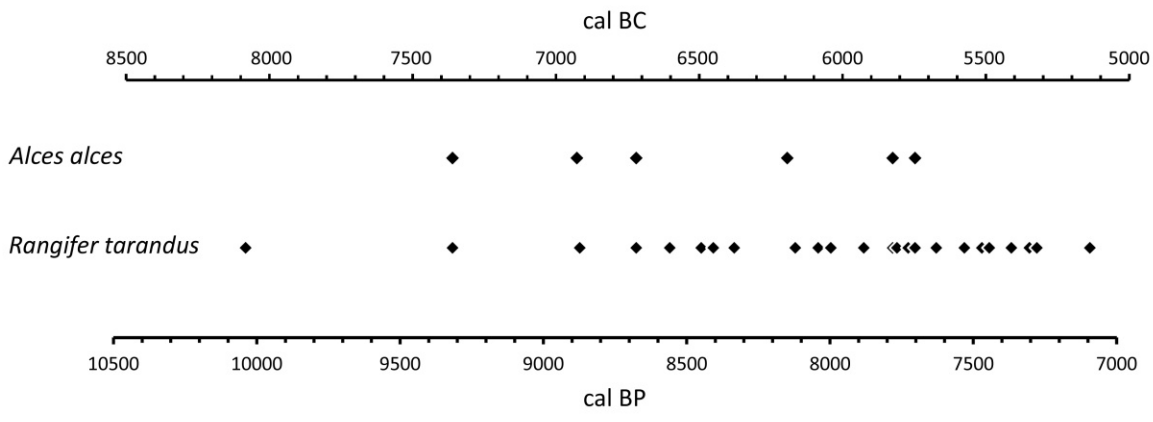


FIGURE 13. Calibrated radiocarbon date median values for European elk (Alces alces) and reindeer (Rangifer tarandus) bones from archaeological sites in Utsjoki, Inari, Enontekiö and Finnmark. Data from Hood (2012); Pesonen *et al*. (n.d.); Rankama & Ukkonen (2001); Paper IV. See Appendix I for data.

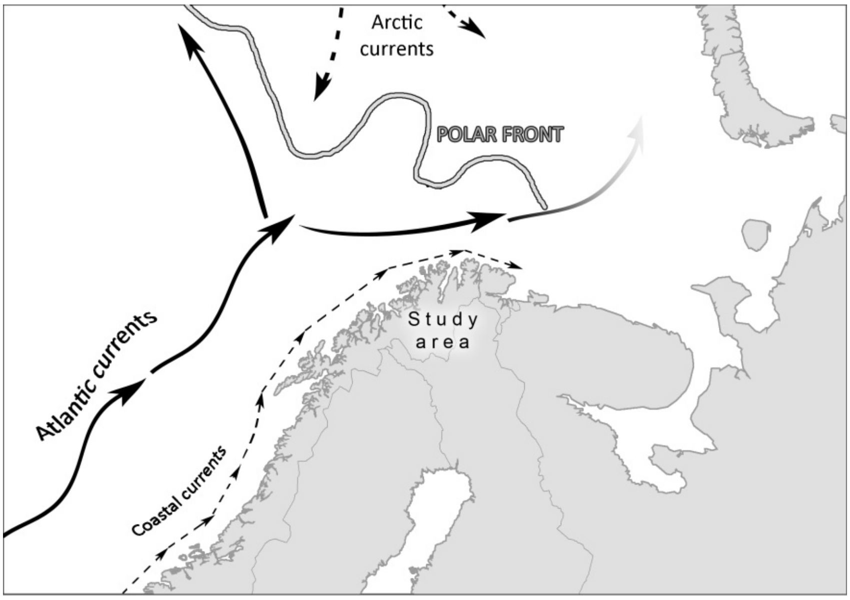


FIGURE 14. The North Atlantic ocean currents in the Barents Sea (Loeng 1991) and the present approximate location of the Polar Front (Risebrobakken *et al.* 2010). Map by the author.

cal BP (Risebrobakken *et al.* 2010), but already prior to this shift, there were gradual changes and rapid events that affected the early Holocene Barents Sea and therefore also the coastal hunter–gatherer communities.

One such event was the Storegga tsunami, which was caused by a major landslide in the Norwegian Sea at *ca.* 8200 cal BP (Hafliðason *et al.* 2005; Romundset & Bondevik 2011). It has been suggested that the tsunami had a catastrophic impact on the Mesolithic coastal societies of the southern North Sea (Weninger *et al.* 2008). Recently, tsunami deposits have been studied in several locations on the Finnmark coast and dated to *ca.* 8200–8100 cal BP, which is consistent with the dating of the Storegga tsunami (Romundset & Bondevik 2011; see also Hagen 2011). According to these studies, an abrupt water run-up of 3–5 metres occurred on the Norwegian Barents Sea coast at the time, causing severe erosion and, among other things, inundating several lakes located close to the shoreline.

The development of the marine biotic environment is less well understood, however. Currently, the Barents Sea has high biological productivity and it supports a wide variety of species, of which especially the fisheries are of particular commercial importance (Gjøsæter 2009). Unfortunately, there are no data that can be used to evaluate directly the early Holocene species composition in the Barents Sea or the abundance or composition of the species sought after by maritime-adapted Mesolithic hunter–gatherers. Currently, the earliest evidence of prey species composition comes from a single midden in the Mortensnes site in east Finnmark, which has yielded radiocarbon dates ranging from the late mid-Holocene to the late Holocene and indicates the consumption of a range of marine fauna (seal, whale, fish, seabirds, molluscs) similar to that usually found at the coastal late Holocene (post 4200 cal BP) sites in the region (e.g., Hodgetts 1999; Schanche 1988).

The rivershore and lakeshore sites dating to the early Holocene have not yielded fish bones either. However, the runs of anadromous fish species in particular, most notably salmon (*Salmo salar*), along the river systems were most likely an important seasonal food resource for prehistoric hunter–gatherers (Rankama 1996). The impact of climate events on these species and indeed their importance to Mesolithic hunter–gatherers is difficult to assess, however, because of riverbank erosion that has destroyed many of the potential river-bound sites

(Rankama 1996) and the poor preservation of Salmonidae bones in the area (Ukkonen 1997).

1.7. Aims of the thesis

Although technological and thus also cultural changes in northern Fennoscandia seem to roughly coincide with the 8200 cal BP event, the mechanism leading to these changes, the effect of the cold event on hunter–gatherer ecosystems in the area, and indeed the possible causality between the climate event and the cultural changes have remained largely unstudied (but see Hagen 2011). In this dissertation, I attempt to shed light on these questions while at the same time providing a more detailed picture of the Late Mesolithic margin-retouched point technology and its relationship to other Mesolithic traditions in Fennoscandia.

Because it is evident that climate does not have a direct impact on lithic technology, the evaluation of constraints in both the physical and social environments that potentially affect human behaviour and the evolution of lithic technology in the studied part of Europe make up an important part of the thesis. Previous research has shown that changes in lithic technology occurred during the Late Mesolithic in northernmost Fennoscandia and that the changes in primary lithic production, as well as in arrowhead technology and distribution, can be considered the most visible and easily recognisable signs of these changes in Finnmark and northern Finnish Lapland.

However, to be able to study whether and how the 8.2 ka cold event might have triggered the chain of events that led to new technology and especially to the spread of the margin-retouched point concept, it is first necessary to know the date, extent, and ecological and technological contexts of the Late Mesolithic margin-retouched point "phenomenon", irrespective of present-day national borders. Such a survey makes it possible to better evaluate how the margin-retouched point sites in the inland areas of Finnmark and in northern Finnish Lapland are connected to the Barents Sea coastal sites and whether causal relationships between the changes that occurred in the two areas can be detected.

The fact that lithic raw materials from the Barents Sea coast have also been found in connection with the new point type in the inland region suggests that there was a change in the organisation of land use and/or in hunter–gatherer social networks (*sensu* Whallon 2006) towards the end of the Mesolithic. The settlement configurations and patterns of lithic raw material movement and use indicated by the Late Mesolithic margin-retouched point sites and technology therefore need to be studied. The underlying assumptions are that the most prominent consequences of the 8.2 ka event in the study area are likely to have been related to the availability and distribution of food resources and that by studying the organisation of technology and land use it is possible to better evaluate whether the changes in lithic technology were linked to changes in resource availability due to the abrupt climate change.

Focusing on the margin-retouched points as an indicator of the new technology, I try to grasp both cultural factors (technological traditions and transmission of culture) and factors in the natural environment (food resource availability, raw material availability and raw material properties) that could explain the development and spread of this arrowhead manufacturing concept during the Late Mesolithic in areas that are often considered to represent separate cultural and technological traditions during much of the earlier Mesolithic period. The interconnected goals of the thesis can thus be summarised as follows:

- To study the date and extent of Late Mesolithic oblique point use in northernmost Fennoscandia and its relation to earlier technological traditions in the area, as well as to the Late-Mesolithic margin-retouched points in more southerly Finland and beyond.

- To study the settlement configuration represented by the Late Mesolithic margin-retouched point sites in northernmost Fennoscandia, as well as the organisation of technology at these sites, while trying to understand the effects of the differing properties and availability of vein quartz *versus* raw materials of better controllability and workability on the technology.

- To evaluate whether the introduction of the margin-retouched point concept to the inland areas of northernmost Fennoscandia and the contemporaneous changes in lithic technology in the study area can be linked to abrupt climate change.

2. THE THEORETICAL AND METHODOLOGICAL FRAMEWORK OF THE STUDY

In terms of theory, the framework of the dissertation can be defined as Darwinian. The study is informed by two complementary approaches, namely *cultural transmission theory*, a segment of dual inheritance (or co-evolutionary) theory (*cf.* Bentley *et al.* 2008; Boyd & Richerson 1985; Collard *et al.* 2008; Eerkens & Lipo 2007; Johnson 2010; Richerson & Boyd 2005) and evolutionary or *behavioural ecology* (*cf.* Barton & Clark 1997; Kelly 1995; Surovell 2009; Winterhalder & Smith 2000). Human behavioural ecology can be defined as the study of evolution and adaptive design in an ecological context (Winterhalder & Smith 1992:3) that is particularly focused on the way natural selection shapes human societies. Cultural transmission theory, on the other hand, seeks to explain the evolution of culture.

In cultural transmission theory, cultural traditions are viewed as products of socially transmitted ways of thinking, while innovation, random choice, selection, and mechanisms of social transmission are considered comparable to the concepts of natural selection, genetic inheritance, mutation, and drift in biological evolution (Boyd & Richerson 1985; Cavalli-Sforza & Feldman 1981; Newson *et al.* 2007; Shennan 2005; 2008). Culture is consequently seen as a means of adaptation that produces non-biological responses to environmental stresses and thus potentially reduces the need for genetic evolution as a response to such stresses (Boyd & Richerson 2005).

The evolutionary framework and the organisational approach (see below) of this dissertation offer the advantage of enabling the use of hypotheses that can be tested using archaeological and ethnographic data and re-tested when new data become available. In addition, ecologically oriented studies in archaeology are beneficial to studies of any and all aspects of human behaviour, regardless of theoretical orientation, as they provide an understanding of environmental constraints on behaviour that acknowledges the inescapable role of humans as a part of the ecosystem. An understanding of the ecological factors that have affected human behaviour thus provides a baseline against which socially governed behaviour can also be studied.

Behavioural ecological studies are

conducted to detect underlying causal variables in human behavioural diversity by designing and testing hypotheses of optimal patterns of behaviour (Broughton & Cannon 2010b; Broughton & O'Connell 1999; Cronk 1991; Winterhalder & Smith 2000). Studies conducted within such a framework usually investigate hunter–gatherer adaptations by modelling optimal solutions to foraging problems for the purpose of identifying those features in the environment that have affected human behaviour and its evolution. In fact, rigorous mathematical formalism can be considered an important quality of evolutionary ecology as a whole (Surovell 2009; Winterhalder & Smith 2000). This quality distinguishes the present study from mathematically oriented evolutionary ecological research because although the goal here is to study evolution and adaptive design in an ecological context, the models in this study, as in much of the research utilising the organisational approach to the study of technology (e.g., Andrefsky 1994; Binford 2002; Johnson & Morrow 1987; Kelly 2001; Kuhn 1994; Nelson 1991; Shott 1986), are informal.

In this dissertation, I therefore try to understand the roles of the physical environment and the evolution of socially transmitted technological traditions in a specific hunter–gatherer context. By doing so, I attempt to avoid explanations that relate all variation in human behaviour to either social causes or rational choice. At the same time, the study contributes to the understanding of the effect of socially transmitted information on the organisation of prehistoric technology (*cf.* Kelly 1995: 58–62; Moore & Newman 2013).

2.1. The organisational approach in hunter–gatherer research

I use an organisational approach to study the settlement configuration represented by the Late Mesolithic inland margin-retouched point sites and its relation to changes in stone tool production technology. This approach has its roots in archaeological studies of human behaviour and especially in the formulation of methods of inference for (Binfordian) middle-range theory (e.g., Binford 1978; 1979; Maschner 1996; Nelson 1991; Schiffer 1976). The approach can be used to identify factors that affect the organisation of sites and activities using behavioural inferences drawn from ethnographic and ethnoarchaeological research by assessing their effect on such archaeologically detectable aspects of past societies as technology, site structure, and settlement configuration. Ethnoarchaeological investigations and ethnographic data suggest that there are several common denominators that characterise mobile camp sites, such as small dwellings and small site sizes, low investment in housing, high feature discreteness, low degrees of debris accumulation, and low preventive site maintenance (e.g., Binford 1990; Chatters 1987; Gamble & Boismier 1991; Gould 1971; Jones 1993; Kelly *et al.* 2005; Kent 1991; Panja 2003; Paper V).

However, when studying aspects of past hunter–gatherer life that are not relevant to the majority of contemporary hunter–gatherers, such as stone tool production and use, inferences about factors that shaped their organisation in the past cannot, in most cases, be tested against ethnographic data. Instead, constraints on human behaviour imposed by such variables as lithic raw material availability (and its relation to settlement configuration) are studied by formulating models that use currencies borrowed from economics, such as utility, efficiency, and risk and by testing the models against archaeological data (e.g., Kelly 2001; Nelson 1991; Surovell 2009; Torrence 1983; 1989). Most studies of lithic technological organisation therefore strive to study the relationship between a constraint and the optimisation of some currency, a fact that indicates obvious rallying points with more formal evolutionary ecological approaches (Jochim 1989; Surovell 2009:10).

Among the reasons that northern Fennoscandia is a study area well suited to the objectives of this study, especially with respect to changes in prehistoric hunter–gatherer lithic technological organisation, are its great variability in stone tool technology throughout prehistory (e.g., Hesjedal *et al.* 1996; Kankaanpää & Rankama 2005; Nummedal 1929; Rankama 1997; Woodman 1999) and the clear-cut division in lithic raw material availability. These qualities facilitate the study of raw material and artefact movement in the area and therefore offer a good platform for studying factors involved in the way lithic technology was organised in relation to raw material availability and properties, especially when combined with knowledge of settlement configuration, economic organisation, and lithic technological traditions.

A central avenue of investigation in studies of lithic technological organisation over the years has been the relationship between the organisation of hunter–gatherer land use and stone tool technology (e.g., Andrefsky 1994; Bamforth 1991; Blades 2001; Carr 1994; Johnson & Morrow 1987). Many studies have considered formal lithic technologies, such as blade production and bifacial flake cores, which are advantageous for mobile groups because of such benefits as low carrying costs and raw material conservation (e.g., Hertell & Tallavaara 2011b; Kelly 1988; Parry & Kelly 1987; Rasic & Andrefsky 2001), particularly when there is a limited supply of raw materials of good workability and controllability (Andrefsky 1994). This has led some researchers to erroneously equate high mobility with formal lithic technology (*cf.* Bamforth 2009; Paper V).

As noted by Kuhn (1994; see also Surovell 2009:142–150), if mobile tool kits are designed to maximise durability and functional versatility while simultaneously minimising weight, the carrying of formal prepared cores is not necessarily more advantageous in terms of transportation costs than is the carrying of small flake blanks and tools. Recently, the superiority of formal prepared cores, in comparison to informal flake cores, in terms of raw material conservation, has also been questioned (Eren *et al.* 2008; Jennings *et al.* 2010; Prasciunas 2007).

This dissertation contributes to this discussion by providing an example from an area where sources of lithic raw materials of good flakeability and predictability are restricted and localised and by studying sites where these raw materials were used in arrowhead production, despite these sites being located at considerable distances from the raw material sources. At the same time, the widely available vein quartz, which is infamous for its poor predictability and controllability (e.g., Callahan 1979:16; Cotterell & Kamminga 1990:127; Siiriäinen 1981b), was commonly utilised at these sites and thus had a role in the way technology was organised by constituting a major factor in the “n-dimensional mesh” of organisational dimensions (*cf.* Chatters 1987; Bamforth 2009).

Knowledge of the movement and use of lithic raw materials has also been employed in earlier studies of land use patterns and settlement configurations in the area (e.g., Grydeland 2000; Halinen 2005; Havas 1999; Hood 1992b; 1994; Rankama & Kankaanpää 2011). However, only Hood (1994) has studied lithic raw material movement in the study area in an organisational framework. It is therefore still largely unknown how raw materials moved in the area and whether the availability of lithic raw materials, stone tool production technology, and the degree of mobility co-vary in the way predicted by models that combine formal lithic production with high mobility and low raw material abundance or whether mobile groups possibly organised their lithic technology otherwise, for instance, by carrying and utilising flake blanks. These questions have obvious relevance when studying the Late Mesolithic changes in the study area, i.e., the changes in raw material use and blank production, as well as the spread of the flake-based margin-retouched point technology.

2.2. The difference between culture and behaviour

Earlier research on the Mesolithic of northernmost Fennoscandia has been conducted within various theoretical frameworks. Nevertheless, most of this research has been interconnected through the use of established typological classifications of lithic artefacts that stem from early culture historical studies and are the basis of defined archaeological cultures. These classifications can be also employed as heuristic devices in current evolutionary approaches (Riede 2006; Riede *et al.* 2012; Roberts & Vander Linden 2011) as they usually succeed in following developments that can be related to the evolution of technological traditions.

However, in large parts of Fennoscandia, classification of lithic artefacts into formal types has not been successful, due to the simple and informal mostly vein quartz-based technology present at Stone Age sites (Knutsson 1998; Rankama *et al.* 2006; Siiriäinen 1981b). Although this situation is most likely more challenging for the researcher than for the prehistoric inhabitants of the area, it nevertheless adds to the importance of studying the impact of differences in the natural environment, not only in lithic technology but also in the transmission of culture. Following the definition used in the framework of cultural transmission theory, in the coceptual framework of this study, culture is understood as socially transmitted information on cultural variants that is capable of affecting an individual's behaviour, and unlike individually learned behaviour, culture is inherited in potentially endless chains (Boyd & Richerson 1985; Richerson & Boyd 1992).

The distinction between culture and behaviour, as well as the products of behaviour, such as artefacts, need to be emphasised when culture is seen as socially transmitted information. Behaviour is considered to be a product of both cultural factors and factors in the physical environment, which means that two individuals sharing the same cultural tradition may act differently in different environmental settings (Boyd & Richerson 1985; see also Binford 1973). Hence, changes and differences in the physical environment, such as raw material properties and availability or changes in the ecosystem may cause differences in behaviour (and artefacts) that are not directly influenced by cultural factors.

However, although social learning is considered to be a transmission mechanism that is in many ways comparable to genetic inheritance in biological evolution, it is acknowledged that there is a clear difference between genetic inheritance and the inheritance of socially transmitted information. The mechanisms operating in the latter are much more diverse and involve, for instance, commonly occurring horizontal transmission (**Fig. 15**), which is very rare for genetic information, as well as decision-making forces, i.e., learning biases, some of which increase the number of cultural variants within populations and others of which reduce variation (Boyd & Richerson 1985; Cavalli-Sforza & Feldman 1981; Newson *et al.* 2007; Richerson & Boyd 1992; 2005; Shennan 2005). In certain situations, the way

FIGURE 15. Simple model of cultural transmission. In comparison to biological evolution, cultural evolution is made more complex by the transmission of cultural variants horizontally (between peers) and obliquely (from more experienced non-parents to less experienced individuals). Modified from Cavalli-Sforza & Feldman (1981); Hewlett & Cavalli-Sforza (1986); see also Newson *et al*. (2007).

	Modes of cultural transmission			
	Vertical or parent-to-child	Horizontal or contagious	One-to-many	Concerted or many-to-one
Transmitter	Parent(s)	Unrelated	Teacher/ leader/ media	Older members of social group
Transmittee	Child	Unrelated	Pupils/ citizens/ audience	Younger members of social group
Acceptance of innovation	Intermediate difficulty	Easy	Easy	Very difficult
Variation between individuals within population	High	Can be high	Low	Lowest
Variation between groups	High	Can be high	Can be high	Smallest
Cultural evolution	Slow	Can be rapid	Most rapid	Most conservative

cultural variants are transmitted can also produce maladaptive results such as loss of technology (Henrich 2004; Riede 2009b).

When discussing material culture, as is the case in most parts of this study, it is important to note that the modes of cultural transmission that affect the frequency of cultural variants within populations, as well as other mechanisms of cultural evolution, can also be expected to influence artefact populations, i.e., the archaeologically visible representations of social learning/cultural transmission and shared traditions (*cf.* Mesoudi & O'Brien 2007). It is assumed that the way information is transmitted has a bearing on the relative amount of variation within artefact groups (Bettinger & Eerkens 1997; 1999; Eerkens & Lipo 2007).

2.3. Technological traditions and cultural inertia

The fact that representatives of groups with different cultural histories often behave differently even when inhabiting similar environments and performing similar tasks, i.e., that a large amount of cultural diversity exists among human societies, is explained by *cultural inertia* in cultural transmission theory. The possibility of horizontal transmission of culture between representatives of the same generation enables potentially rapid culture change in situations in which rapid changes make earlier adaptive solutions useless or impractical, such as during abrupt ecosystem crises (*cf.* Acerbi & Parisi 2006). Nevertheless, it is argued that due to cultural inertia, changes in cultural traditions in response to (gradual) environmental change should usually be slow and that history should explain a significant fraction of present behaviour (Boyd & Richerson 1985:56–60; see also Pagel & Mace 2004; Shennan 2009). The reasons for these phenomena can be found in the way people acquire most of their skills, i.e., by imitation and social interaction, and the way in which language differences and boundaries to movement consequently prompt cultural divergence that is self-reinforcing (Boyd & Richerson 2005:379–396; Pagel & Mace 2004).

3. MATERIAL AND METHODS

3.1. The archaeological sample

The material used to study the Late Mesolithic changes that are the main focus of the dissertation can be divided into four parts. The first part consists of the data concerning the distribution and date of margin-retouched points in Fennoscandia (Papers I and IV). The second part is a dataset on Late Mesolithic margin-retouched point shape, raw material, and technological characteristics in two separate areas in Finland (Paper IV), the third consists of the finds, reports, and documentation from excavations conducted at Mesolithic sites in northernmost Fennoscandia (Papers I, II, IV, and V), and the fourth is an experimentally produced series of quartz fractures (Paper III).

Two sets of sites were selected for analyses of technological organisation, settlement configuration, and cultural evolution. The first set consists of five inland sites, two in northern Finland (Vuopaja and Mávdnaávži 2), two in northern Norway (Devdis I and Aksujavri), and one in northern Sweden (Rastklippan). This set of sites was used for a detailed study of raw material use, site structure, and operational sequences at margin-retouched point sites in the inland areas of northernmost Fennoscandia (**Fig. 16**). The five sites were selected on the basis of the presence of an excavated occupation phase with associated margin-retouched points and reliable radiocarbon dates (Paper V). When compared to sites located on the Barents Sea coast, the inland sites provide clear advantages for the study of Late Mesolithic lithic technology. This is because earlier research has not revealed any indications of margin-retouched point use in the inland region prior to the Late Mesolithic, and because the geological features of the area are such that the use and movement of exotic raw materials is easier to detect and study along a gradient of increasing distance from the Caledonian nappes.

The second set of sites was selected for the purpose of a technological comparison between points found in southern Finland and counterparts found in northern Lapland. The sites selected for the comparison are located south and north of an empty area in the point

FIGURE 16. A view towards Lake Akšojavri and the Kautokeino River from the Aksujavri site in Finnmark, Norway (Hood 1988) (top) and excavations in progress at the Mávdnaávži 2 site, Utsjoki, Finland. From right to left: Hanna Suisto, Meri Varonen, and Esa Hertell. The Aksujavri site has had an important role in discussions concerning the Mesolithic use of interior Finnmark. The Mávdnaávži 2 site, on the other hand, can be considered a key site in the interpretation of artefact distributions and site structure at Late Mesolithic margin-retouched point sites. Photographs by the author.

distribution that lies in southern Lapland (Paper IV). A sample of 30 sites and find locations with a total of 196 artefacts reported as oblique points was analysed for technological details.

3.2. Dating methods and survey of distribution

The data on the distribution and dates of margin-retouched points in Fennoscandia were gathered from research literature as well as from unpublished survey and excavation reports in Finland, Sweden, and Norway (Papers I, II, and IV). To supplement the existing radiocarbon date data, seven samples from oblique point contexts were selected and dated for the purpose of this study (Paper IV). All radiocarbon dates were calibrated using OxCal version 4.1.7 or later (Bronk Ramsey 2010) and the IntCal 09 calibration curve (atmospheric data from Reimer *et al.* 2009), unless otherwise indicated. The calibration procedure used for samples with probable marine reservoir effect (Baltic Sea) is described in Paper IV. Possible cultural boundaries were outlined by comparing the distribution of Late Mesolithic margin-retouched points to those of preceding and contemporary technological traditions (Papers I and IV).

The shore displacement chronology of Mesolithic sites on the Finnish Baltic Sea coast compiled by Matiskainen (1982; 1989) was also utilised, and to a small degree refined, in this study (Papers I and IV). In addition, the find locations of margin-retouched points on the southern shore of Varangerfjord, Norway, were shoreline dated to gain a better understanding of their chronological position on the Finnmark coast. The shoreline dating procedure is described in Paper I. The origin and history of descent of the oblique point was studied by comparing the dates and distributions of margin-retouched points in nearby areas and by using radiocarbon dates to study the most probable direction of spread of the new point type within eastern Fennoscandia. The method is described in more detail in Paper IV.

3.3. Lithic analyses

Details of stone tool production technology and operational sequences used at the studied sites were inferred using basic debitage typological and aggregate analyses and analyses of flake tool attributes (*cf.* Andrefsky 1998; 2001). A special effort was also made to increase the understanding of quartz fracture mechanics and the properties of vein quartz in lithic production and use by experimentally producing data on quartz fragmentation patterns (Paper III). Because of the restrictions on lithic production caused by the high fragmentation tendency of quartz (Callahan *et al.* 1992) the type of effect the use of quartz had on the way technology was organised was also studied (Papers III, IV, and V).

The debitage typological analyses were designed to provide an overview of the nature of the studied site assemblages. The material was classified into flakes, cores, and tools. Following the convention in Fennoscandian quartz studies (e.g., Callahan 1987; Darmark & Sundström 2005; Lindgren 2004; Rankama 2002; Paper III), flakes and cores were divided into *platform vs. bipolar* flakes or cores, depending on the reduction method (platform core of bipolar-on-anvil core reduction). This procedure deviates slightly from the most conventional approach to lithic technological classification, according to which platform reduction is considered the norm, while bipolar flakes and cores are treated as special debitage classes. However, due to the common use of bipolar reduction in quartz flake production in Fennoscandia (and elsewhere; see Paper III), in debitage typological analyses of assemblages, including quartz artefacts, it is better not to consider one of the two reduction methods as the norm.

Flake tool attributes were studied from retouched artefacts and especially margin-retouched points. As it was suspected that differences in within-group variation could indicate differences in transmission mechanisms (*cf.* Bettinger & Eerkens 1997; 1999), the measurable characteristics of point shape and dimensions of two point populations in Finland, one in the north and one in the south, were studied. The measured attributes are described in Paper IV.

The aggregate analyses used in the study include Minimum Analytical Nodule analysis (Larson 1994; Larson & Kornfeld 1997; Tallavaara 2005; Papers II and V) and basic size-graded debitage analysis (Andrefsky 1998:128–131; Paper II). Using a variation of Minimum Analytical Nodule analysis, the movement and utilisation patterns of lithic raw materials were studied by dividing site assemblages into analytical nodules according to visual raw material characteristics. The results of this division were combined with the results of debitage typological analyses to make inferences about future activity planning, adaptive strategies, and mobility patterns at the studied sites.

Due to the generally small size of lithic artefacts in the studied assemblages, as well as the small sizes of the site assemblages, no size cut-off was used in the Minimum Analytical Nodule analysis. The same was also true for the refitting (*cf.* Cziesla 1990) of the Mávdnaávži 2 lithic material, the results of which were used to confirm the picture of on-site activities given by find distributions at the site (Papers II and V).

3.4. Spatial analyses

The site structure and spatial organisation at the Late Mesolithic margin-retouched point sites (Papers I and V) were studied using artefact distributions and their relationship to hearths and other site features. The degree of preventive site maintenance and organisation of on-site activity was inferred from the patterns of find distribution and density and using behavioural inferences of settlement configuration and future activity planning, as well as group size and composition, drawn from ethnographic and ethnoarchaeological research (Paper V).

3.5. Statistical methods

Basic statistics were used in the analyses of the data gathered and used in the different parts of the study. The statistical analyses were conducted in part by Miikka Tallavaara (Papers III and IV) and in part by the author (Papers IV and V). The data treatment procedures and the inferential statistical analyses (comparison of paired correlations and coefficients of variation, correspondence analysis, log-linear modelling, and logistic regression) are described in the individual papers. Descriptive statistics were used to provide simple graphic summaries (box plots, scatter plots, line charts, bar charts, and cross tabulations) of the analysed data (Papers I–V).

4. RESULTS AND DISCUSSION

4.1. Dates, distribution, and descent

The radiocarbon-dated inland contexts in northernmost Fennoscandia, as well as the radiocarbon- and shoreline-dated sites in Sweden and more southerly Finland (Papers I, II, IV, and V), indicate that south of the Barents Sea coastal sphere, the use of margin-retouched points is a Late Mesolithic phenomenon, with the majority of dates falling between 8500 and 7000 calibrated radiocarbon years BP (**Fig. 17**).

The distribution of sites with margin-retouched points in Finland, Sweden, and northern Norway (**Fig. 18**; Papers I and IV) shows that in northern Sweden, the points are rare (4 reported sites) whereas in Finland and northern Norway, Late Mesolithic sites with such points are relatively numerous (over 160 reported sites). The results thus indicate that during the Late Mesolithic, virtually identical arrowheads were in use in both coastal and inland settings in eastern Fennoscandia, from the Barents Sea coast in the north to the Gulf of Finland in the south (Papers I and IV). In both areas, the arrowhead concept fell out of use at approximately 7000 cal BP, after the introduction of Comb Ware pottery, which in eastern Finnmark and in the Lake Inari region has often been found at sites that have yielded also oblique points (Luho 1957; Skandfer 2003; 2005; Papers I, II, and IV).

An evaluation of the most likely scenarios for the descent history of the arrowhead manufacturing concept, in light of the current evidence, suggests a descent from the early post-glacial projectiles of north-central Europe via the Norwegian Atlantic coast (Paper IV). Moreover, although the dates are not numerous, the fact that the earliest dates from oblique point contexts in Finland derive from northern Finnish Lapland suggests that in eastern Fennoscandia, the arrowhead concept spread from the north towards the south (Paper IV).

When discussing change in technological traditions in northern Fennoscandia, it is important to consider the way the earliest pioneer colonisation of the area followed relatively closely the retreating Scandinavian Ice Sheet. Both archaeological finds and the dynamics of ice sheet retreat suggest that at least

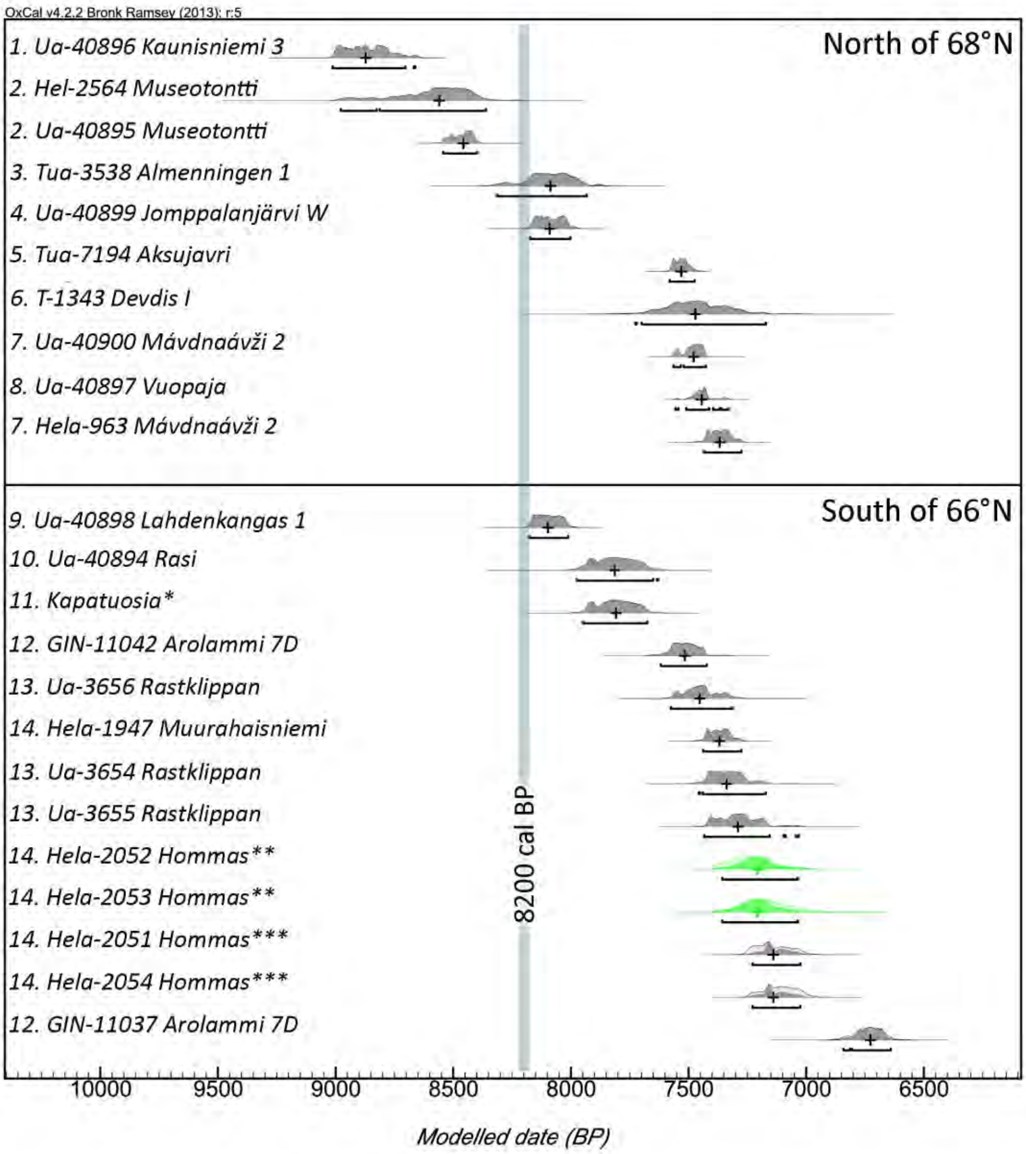


FIGURE 17. Radiocarbon dates of margin-retouched point contexts from inland sites in northernmost Fennoscandia and sites in more southerly Finland and Sweden (there are no radiocarbon-dated point contexts between 66–68°N; see Figure 18 for site locations). See Papers I, IV, and V for references, except for Almanningen 1 (Blankholm 2008), Muurahaisniemi (P. Pesonen pers. comm.) and Kapatuosia (MJrek 2013). *Lab code unpublished. **Hela-2052 and Hela-2053 calibrated using the Marine09 calibration curve (Reimer *et al*. 2009) with Delta_R LocalMarine -80 (Olsson 1980; Stuiver *et al*. 1986–2010). ***Hela-2051 and Hela-2054 calibrated using a combination of corrected Marine09 (Delta_R LocalMarine -80) and IntCal 09 curves, with estimated 50% terrestrial and 50% marine diet. Atmospheric and marine data from Reimer *et al*. (2009).

two pioneer populations with substantially different adaptations and lithic technological traditions moved into northern Fennoscandia at the end of the last glacial cycle (**Fig. 19**; see also Knutsson 2004; Kosheleva & Subetto 2011; Rankama & Kankaanpää 2008; 2011; Tallavaara *et al. in press*). The first of these populations consists of groups using margin-retouched points that colonised the Norwegian Atlantic coast and most likely descended from the Upper Palaeolithic groups of north-central Europe (Bjerck 2008; Fuglestvedt 2007; Waraas 2001; Paper IV), while the second represents groups belonging to the so-called post-Swiderian tanged-point cultures that entered the area from the southeast (Rankama & Kankaanpää 2011; Tallavaara *et al. in press*) and probably as a consequence

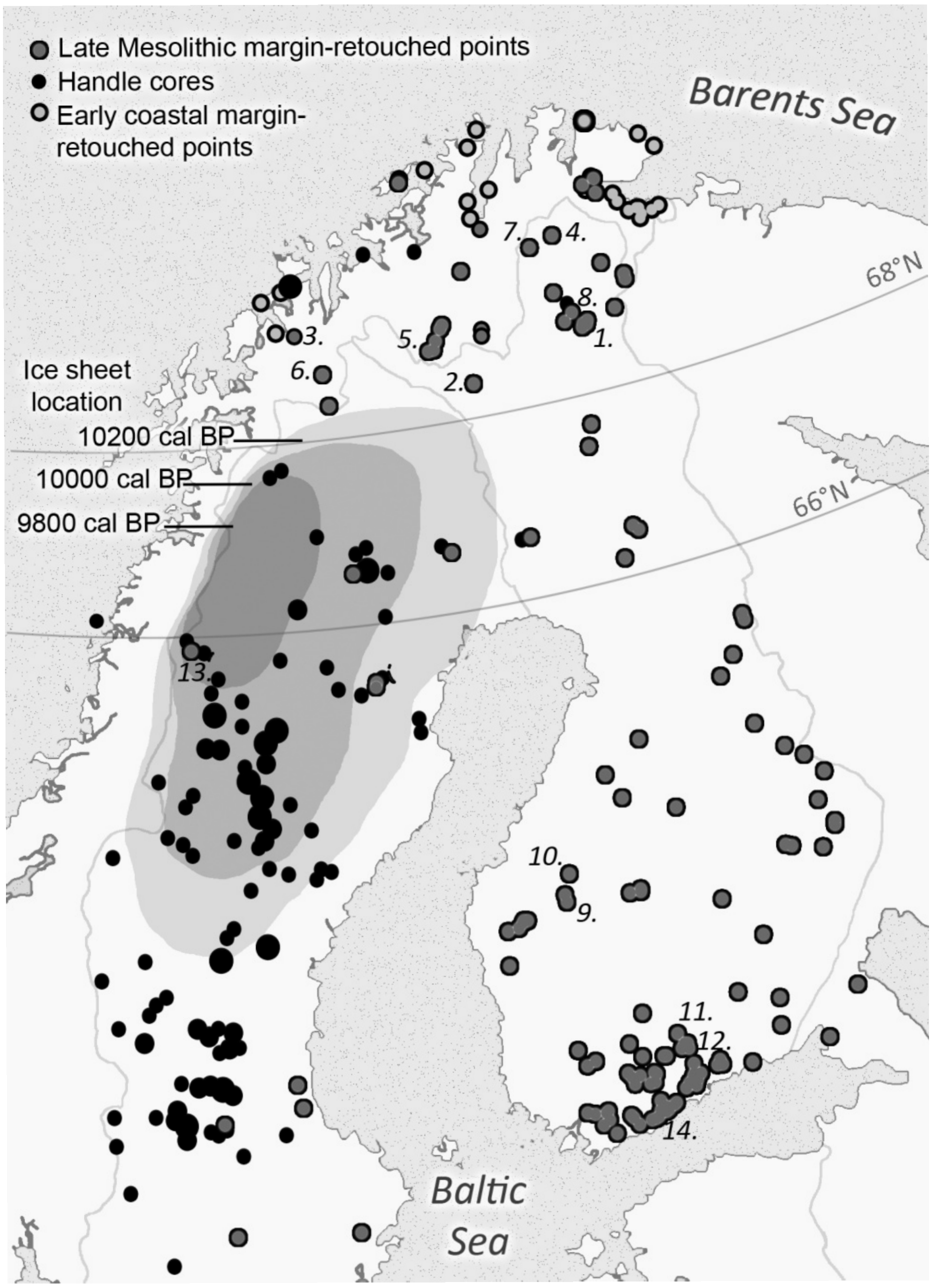


FIGURE 18. The distributions of margin-retouched points and handle-cores. The point distributions are based on Papers I and IV. The distribution of handle core sites is based on Olofsson (1995) and Paper I. Added to the earlier maps are additional finds published by Hood (2012) and the last stages of the retreat of the Scandinavian Ice Sheet (after Daniels 2010; Påsse & Daniels 2011; see also Knutsson 2004:Fig. 6). See Figure 17 for the names and dates of sites 1–14. Map by the author.

of the raw material situation quickly abandoned the formal blade-based technology typical of these groups (Tallavaara *et al. in press*; Paper V). A probable third colonisation front entered the area slightly later from the south, along the Scandinavian Peninsula (Forsberg & Knutsson 1999; Knutsson 2004).

The way the pioneer colonisation of the area took place, due to the barrier formed by the Scandinavian Ice Sheet, thus suggests that the differences in lithic technology between the Barents Sea coastal strip and the inland region of northern Fennoscandia during the early phases of the Mesolithic, in addition to environmental differences, represent a boundary between groups with different descent histories and traditions. It seems plausible that in addition to the self-reinforcing effect of cultural inertia, this boundary was also

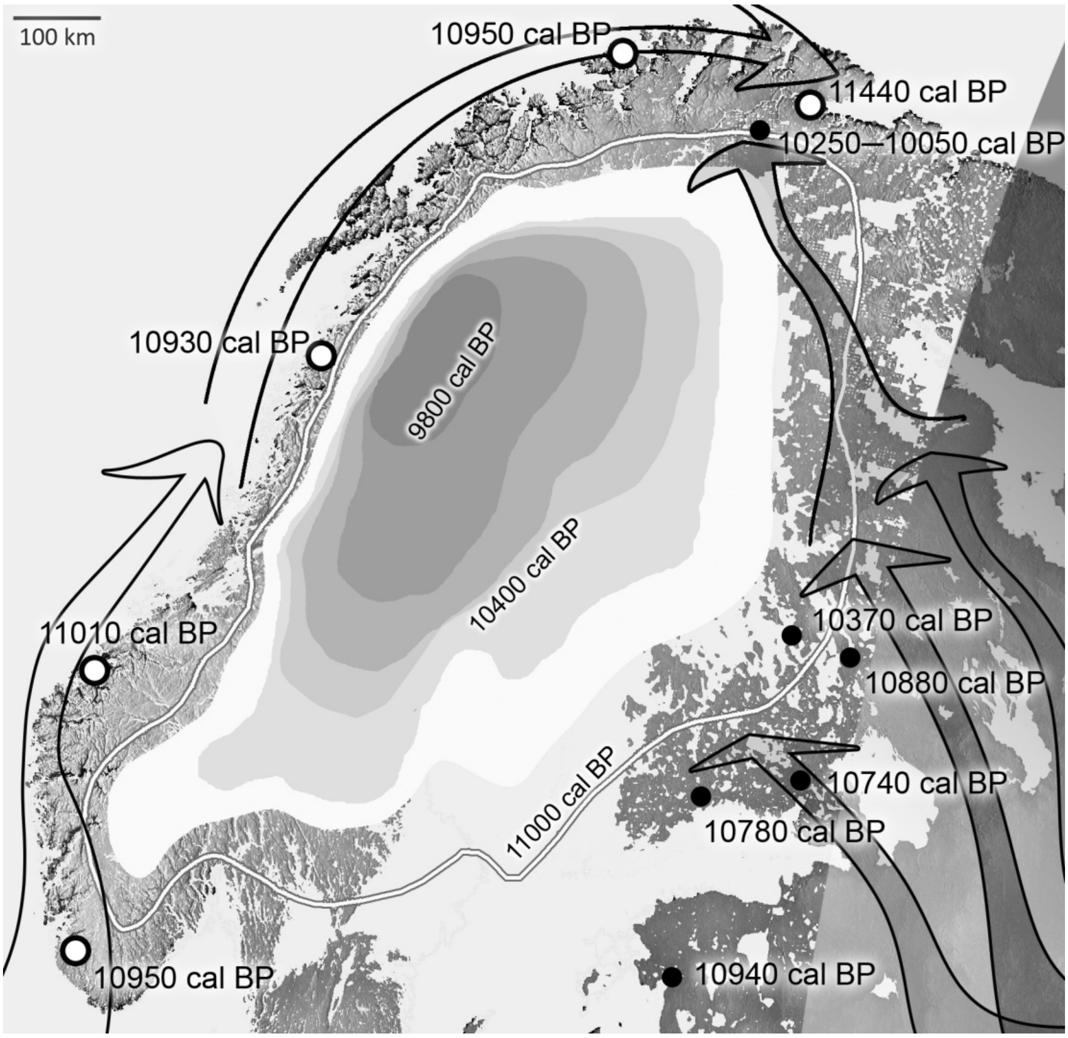


FIGURE 19. Paleomap depicting the retreat of the Scandinavian Ice Sheet and the *ca*. 10800 cal BP shoreline in Fennoscandia (Daniels 2010; Påsse & Daniels 2011), with some of the earliest known sites representing the southwestern (marine) and southeastern (terrestrial) colonisation fronts. The arrows indicate the two directions of pioneer colonisation. Dates and site locations from Bang-Andersen (2012), Bjerck (2008), Jussila *et al*. (2012), Rankama & Kankaanpää (2011), Veski *et al*. (2005) and Tallavaara *et al*. *(in press)*. Map by the author.

later reinforced by the Scandinavian Caledonides (*cf.* Damm 2006).

The current evidence suggests that the margin-retouched point concept was maintained in the Barents Sea coastal sphere for millennia but that only during the Late Mesolithic, at some point in time around the 8.2 ka event, did it cross the cultural and most likely also territorial and linguistic border that the archaeological material suggests existed between groups descending from the early post-glacial coastal pioneers on the one hand and groups descending from the pioneer colonisers that followed the retreating Scandinavian Ice Sheet from the southeast on the other (Paper IV). It seems reasonable to assume that the spread of the technological concept towards the south was triggered by the 8.2 ka event and was accelerated by the Holocene Thermal Maximum and the existence of an established hunter–gatherer network consisting of groups with shared cultural and most likely also linguistic origins that descended from the southeastern pioneer colonisation wave (Papers I, IV, and V).

It must be emphasised that the material culture divide between the interior and the coast in northernmost Fennoscandia was not geographically static during the

Mesolithic. There are also indications that at least one technological concept, namely the post-Swiderian blade-core treatment practises, crossed the border in eastern Finnmark at the end of Mesolithic Phase I and was afterwards gradually transmitted west along the Barents Sea coast (Rankama & Kankaanpää 2011; Sørensen *et al.* 2013).

The existence of long-standing borders between hunter–gatherer networks derived from the period of pioneer colonisation gained support from the distribution of material culture traits in the Late Mesolithic in northern Sweden. Here, the distribution of oblique points can be compared to the distribution of the practically contemporaneous handle cores (*ca*. 8350–6250 cal BP or 6400–4300 cal BC) common in Late Mesolithic Sweden (Knutsson 2004; Olofsson 1995; 2003; Paper I). Only a small overlap in the distributions of the two artefact types exists (**Fig. 18**), and the border zone between the spatially exclusive but temporally synchronous distributions is located in the area where the tail end of the Scandinavian Ice Sheet retreated and fell away at the end of the last glacial cycle (Paper I) and where a long-standing material culture border existed (Knutsson 2004).

The only data available for estimates concerning the temporal relationship between the 8.2 ka event and the Late Mesolithic changes in the inland areas, although still few in number, are the radiocarbon dates from oblique point contexts in Finnmark, Troms, and northernmost Finnish Lapland. There are two radiocarbon-dated oblique point contexts in the interior that predate the event by several hundred years, while the rest of the dated contexts postdate the event. However, if it is accepted that the margin-retouched point concept was present in the coastal sphere from the early pioneer colonisation onwards, it follows that there is no reason to expect that all margin-retouched points in the inland region postdate the 8.2 ka event—even if this seems to be mostly the case. However, the analysed margin-retouched point sites in the interior that postdate the event show that an organisational pattern that suggests a profound reorganisation of technology, land use, and subsistence economy took place across the earlier cultural divide during the Mesolithic Phase III.

4.2. Settlement organisation and site structure

The site structure and patterns of on-site activity at the studied Late Mesolithic inland sites were fairly uniform and suggest short occupation spans. High anticipated mobility is indicated by small dwellings and site sizes, low investment in housing, and high feature discreteness, as well as by low degree of debris accumulation and preventive site maintenance (Papers I, IV, and V). The clearest evidence of this type of behaviour, commonly encountered in association with short-term camps and high residential mobility (*cf.* Binford 2002; Chatters 1987; Gamble & Boismier 1991; Gifford 1980; Jones 1993; Kelly *et al.* 2005; Kent 1991; Panja 2003), is found at the Mávdnaávži 2 site. At this site, feature discreteness is well evidenced in find distribution and low accumulation of lithic debris, as well as in conjoins between burnt and unburnt arrowhead fragments in and around the inside hearth (**Fig. 20**).

The conjoins are clear evidence of lithic production that took place inside the small hut and next to a burning fire. Except for the arrowhead bases thrown into the fire, lithic waste was left where it fell. The most plausible explanation for the clearly low site maintenance is that the site was intended to be abandoned after a short occupation. Although less well preserved, the other studied sites seem to represent almost identical behavioural and organisational

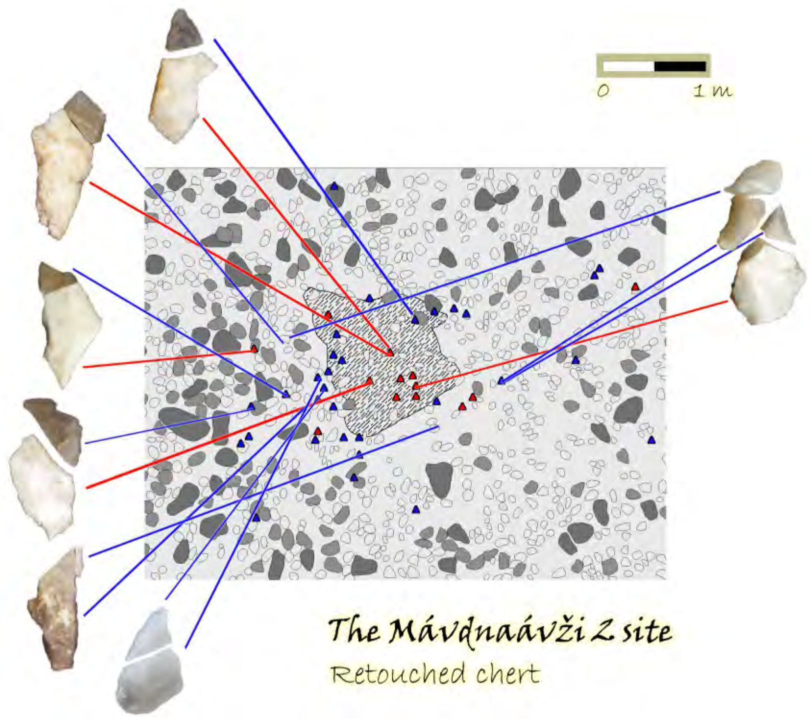


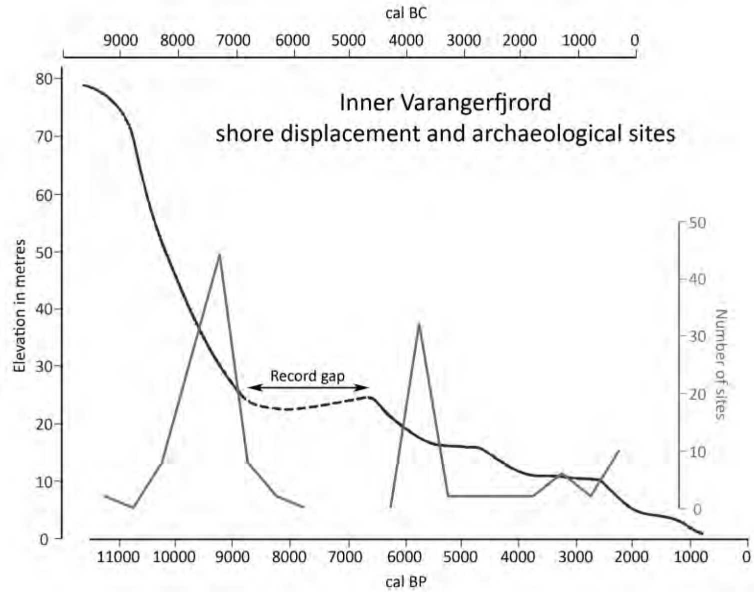
FIGURE 20. Distribution of burnt (red triangle) and unburnt (blue triangle) chert artefacts inside the Mávdnaávži 2 hut. Broken tips of unfinished points and other production waste indicate that arrowhead manufacture took place left of the hearth area (marked with dark grey). The refits and conjoins show a pattern in which the bases of arrowheads broken during manufacture were thrown into the fire. Map, conjoins, and photographs by the author.

patterns (Papers I, II, and V).

The size of dwellings at the studied Late Mesolithic margin-retouched point sites (Paper I and V; see also Grydeland 2000; Odner 1966:75–77) suggests, in addition to high anticipated mobility, that the groups occupying them were small, most likely consisting of only 4–10 individuals (Paper V). Furthermore, the organisation of space inside the dwellings suggests gendered division of labour (*cf.* Grøn 1989; 2003; Paper V) and therefore the presence of both sexes at the sites, which in turn suggests that mobility was in these cases most likely residential.

Significantly, Grydeland (2000: 26, 36, 44) observed a decrease in the number of pit-houses on the southern shore of Varangerfjord in eastern Finnmark at altitudes that are dated to *ca*. 9300 cal BP and later, which can be taken as a sign of increased mobility, smaller groups, and short site occupation spans. The dating, however, is based on a simulated shore displacement curve that suggests that there were no transgressive phases (Møller & Holmeslet 1998). If the altitude data are compared to a shore displacement curve that is based on radiocarbon-dated beach formations (Fletcher *et al.* 1993) and shows a record gap and a plateau at approximately 25 metres above sea level (**Fig. 21**), it becomes clear that the dating of the sites and phenomena in the area on the basis of altitude is not without problems. Radiocarbon-dated sites in the area indicate that during occupation, sites were often located 5 to 20 metres above the contemporary shoreline (Møller 1987; Rankama & Kankaanpää 2011:202). This fact, together with the plateau dating to *ca*. 9300–6600 cal BP caused by a transgressive shoreline, seems to have caused packing of sites at suitable locations between approximately 25 and 37 metres above sea level. Radiocarbon-dated house-pits from Varangerfjord and other locations in Finnmark nevertheless show a pattern of the number of house-pits decreasing towards the end of the Mesolithic (**Fig. 29**), which is in general agreement with the trend observable in many localities in Finnmark where house-pits became smaller and less numerous during Phase III (Grydeland 2000:25–26). After the Late Mesolithic drop, the

FIGURE 21. The number of sites in 500-year blocks according to corrected altitude (reduced by 5 metres) above sea level on the southern shore of the Varangerfjord, n=74 (Paper I) and the Inner Varangerfjord shore displacement curve (Fletcher *et al.* 1993). Site and site altitude data from Bøe & Nummedal (1936); Simonsen (1961); Odner (1966).



number of house-pits starts to increase again approximately 7000–6000 cal BP (Skandfer 2009).

4.3. Lithic technology at the studied sites

The analyses and finds reported in this study (Papers I, II, IV, and V) are consistent with earlier research that suggests that stone tool production technology at sites dating to Phase III in northernmost Finnish Lapland and northernmost Norway was based largely on flake cores and simple tools made on flake blanks (Grydeland 2005; Halinen 2005; Hesjedal *et al.* 1996:186; Olsen 1994:34; Kankaanpää & Rankama 2005).

In the analysed site assemblages, platform flakes were produced using relatively informal cores that give the impression that their treatment was dictated by the initial shape of the objective piece (Paper V). The platform cores are single-platform cores of varied morphology. In many cases, large platform flakes were used as cores in the production of smaller flakes (**Fig. 22**). The cores in the assemblages are small (with maximum dimensions less than 50 mm), which suggests that the shortest acceptable flakes were less than 20 mm in length (e.g., Helskog 1980b: Figs. 26, 27). The lengths of the flakes rarely exceed 40 mm. In addition, the material from Aksujavri, Mávdnaávži 2, and Vuopaja include bipolar-on-anvil cores of quartz.

The majority of tools in the studied site assemblages are thumbnail scrapers and margin-retouched arrowheads made of platform flakes (**Fig. 22a–j, p–s**). In addition, there is a heterogeneous group of flakes and fragments retouched with varying intensity that can be classified as arrowhead preforms, microliths, flake knives, and other indeterminate tools and rejected or discarded pieces (**Fig. 22m–o**).

4.3.1. The arrowhead manufacturing sequence

None of the 246 points included in the analyses conducted in connection with this study (Papers I, IV, and V) show any clear signs of having been produced in another manner than from platform flakes. Maximum arrowhead thickness can be used as an indication of the thickness of flakes used as blanks in point production. In points oriented perpendicular to the blank, point length also gives some indication of the blank width because the points usually have a

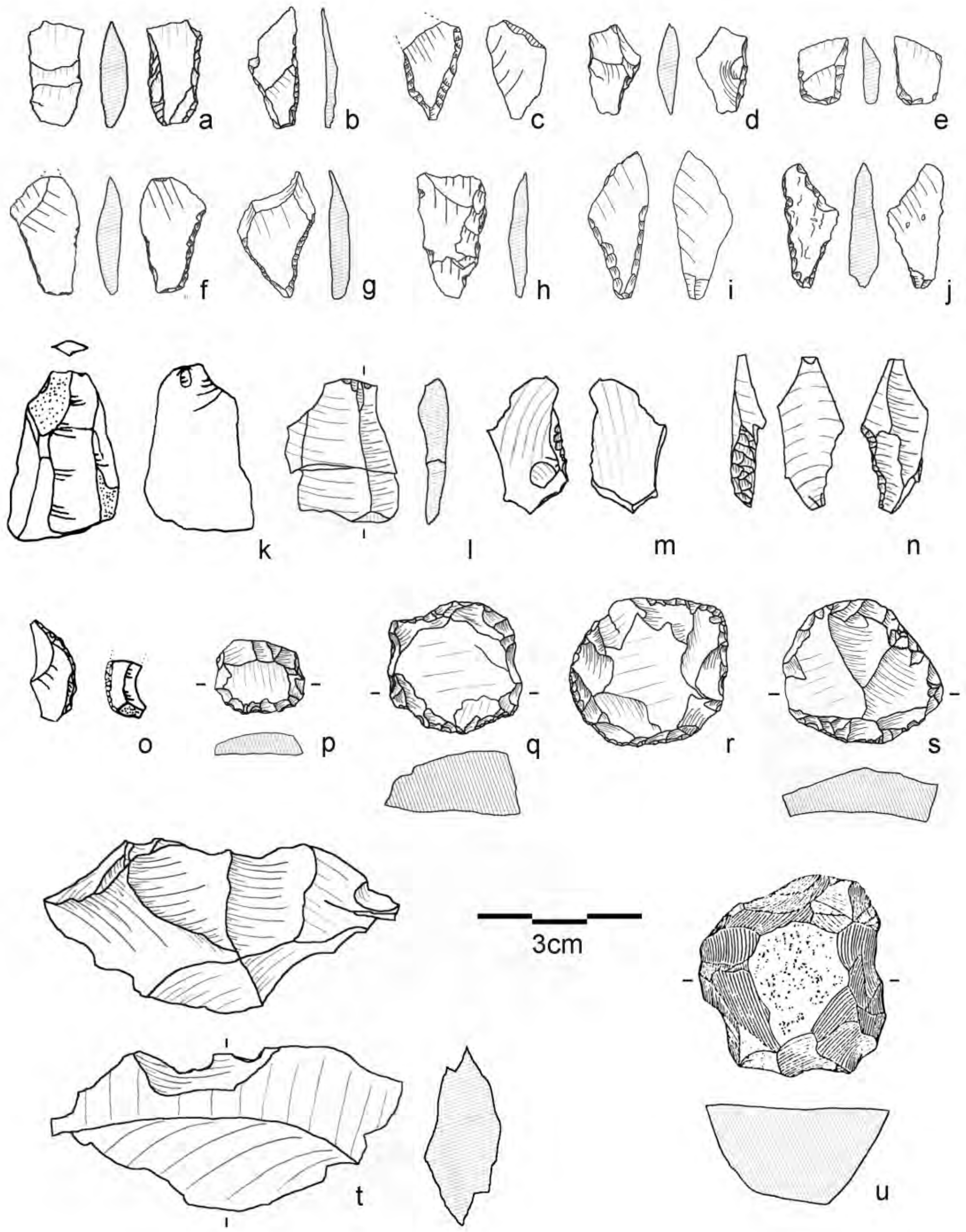


FIGURE 22. Examples of lithic artefacts from the Late Mesolithic margin-retouched point sites. A–i) arrowheads, k–n) flake blanks and arrowhead preforms; o) microliths; p–s) scrapers; t–u) cores. See Papers I and V for site information. The microliths derive from the Mávdnaávži 2 site (Manninen 2005: Fig. 8). All drawings by the author, u) after Helskog (1980b) and c), i), l–n) & t) after sketches by K. Knutsson.

side-view profile with the thickest point near the centre and the cutting edge parallel to a dorsal ridge (Paper IV). For the 158 points analysed in Paper IV, these measurements suggest that the maximum thickness of the blanks was raw material dependent but rarely exceeded 5 mm, while the width of the flake blanks was usually clearly less than 30 mm (the average length of points with perpendicular orientation is 19.2 mm, with a standard deviation of 4.7 mm).

Analyses of edge shapes and angles (Papers I and IV) show that the overall shape of the points varies from transverse points to points with one acute edge angle (between the cutting edge

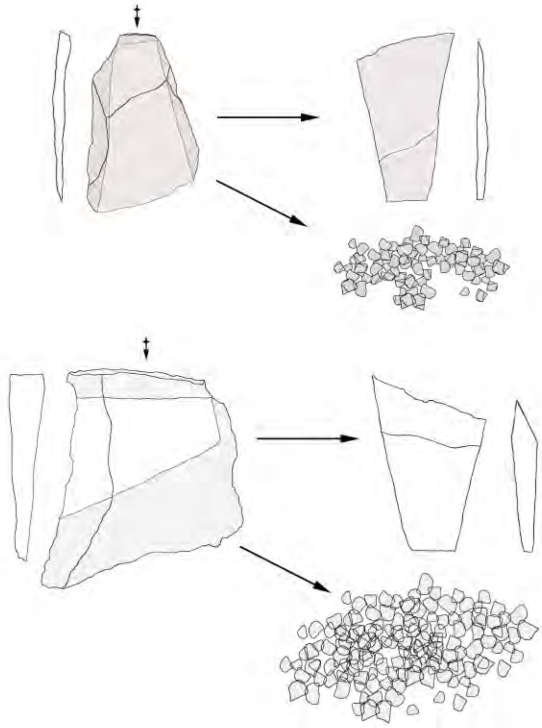


FIGURE 23. Schematic representation of typical blanks, finished products, and waste from Late Mesolithic margin-retouched point production from resilient high-workability raw material (top) and fragile low-workability raw material. Drawing by the author.

and a retouched side) to points with pointed tips. This fact makes the point type variable in form and further indicates that the blanks were of non-standardised shape.

Based on the results presented in the papers, the operational chain of Late Mesolithic margin-retouched point production can thus be summarised as a fairly simple and straightforward sequence in comparison to, for example, arrowhead production utilising formal blades. After relatively thin flake blanks were produced from single-platform cores, the part of the flake-edge considered to be best for the cutting edge of the arrowhead was determined, and finally, the point was shaped by removing the excess part of the blank with semi-abrupt to abrupt margin retouch, thus producing large quantities of small short retouch flakes (**Fig**. **23**). The majority of points were oriented perpendicular to the blank, but points made of chert were almost as often oriented parallel to the blank. If the base of the arrowhead was considered too thick, it was thinned with small semi-invasive to invasive detachments, usually after the point had been otherwise shaped. Only a few slightly deviations from this procedure exist in the studied material (see Paper IV for further discussion).

The comparison of points from northernmost Finnish Lapland and southern Finland reported in Paper IV further indicates that although there are differences between the areas and more variation in the northern group of points, these differences are best explained by the differences in raw material use in the two areas and especially by the properties of vein quartz, i.e., the raw material that was almost exclusively used in the southern points. On the other hand, in comparison to coastal Phase I margin-retouched arrowheads, some clear differences can be detected in the late points. Phase III points tend to be transverse or oblique, whereas the earlier points tend to be tanged single-edged or double-edged (Paper I). The early points also tend to be made on blades (Hesjedal *et al.* 1996:166), whereas the late points are practically always made on flakes.

4.3.2. Patterns of raw material movement and use

A large variety of raw materials is found among the margin-retouched points in northernmost Fennoscandia. In northernmost Finnish Lapland and in northernmost Norway, the arrowheads were made of different varieties of chert and quartzite, as well as from vein quartz and rock crystal (**Table 1**). Of these raw materials, practically all of the varieties of chert and most likely most of the quartzite as well came from sources outside the borders of present-day Finland.

The fact that a relatively large quantity of sites in the Lake Inari region has nevertheless yielded margin-retouched arrowheads made of varieties of chert that originate in the Barents Sea coast indicates that in this technological context, it was not uncommon for lithic raw materials to be carried over 150 kilometres from their sources (Papers I, II, IV, and V). The material from the sites studied in Paper V indicates that arrowheads in particular were produced from chert and other raw materials of good flakeability and predictability, even though the proportion of quartz in site assemblages clearly increases with increasing distance to sources of these types of raw materials (**Fig. 24A**). This suggests that the margin-retouched points of vein quartz, known from three sites in the Lake Inari region and elsewhere (Papers I, II, and IV), were produced only after raw materials of better working qualities were depleted. The distance-decay pattern observable in arrowhead length (**Fig. 24B**) further suggests that the raw materials of good predictability and flakeability were used up gradually, a pattern that points to a growing total of re-tooling episodes with increasing distance from the raw material source (Paper V).

The results of the Minimum Analytical Nodule analysis (Papers II and V) show that each of the studied sites has one or two relatively large analytical nodules and a group of small nodules that in most cases contain less than 10 artefacts and often consist of only retouched pieces. A plausible explanation for this pattern is that large nodules represent on-site manufacture, while small nodules consist of tools and blanks produced elsewhere and brought to the sites as parts of portable tool kits (Paper V). The large variety of raw materials and the types of raw materials found in, for example, the assemblages from Utsjoki and Inari (Papers I and IV), suggests that tool-stone was

Margin-retouched point raw materials in the interior

	Troms	*Finnmark*	*Utsjoki*	*Inari*	*Enontekiö*
Chert/quartzite	35	2			
Chert*		37	14	15	
Quartzite		12		3	
Quartz		1		4	8
Other		1			
Unknown	1				

TABLE 1. Number of points per raw material found in inland sites located in northernmost Finnish Lapland, Finnmark, and Troms, n=134 (Hood 2012; Papers I, II, IV, and V). *Chert includes flint, “dolomite”, Porsanger chert, Kvenvik chert, and other undefined cherts. Chert/quartzite includes points made of raw materials that can be classified as chert or quartzite, often depending on the piece. Rock crystal points are included in the quartz points (*cf*. Paper IV).

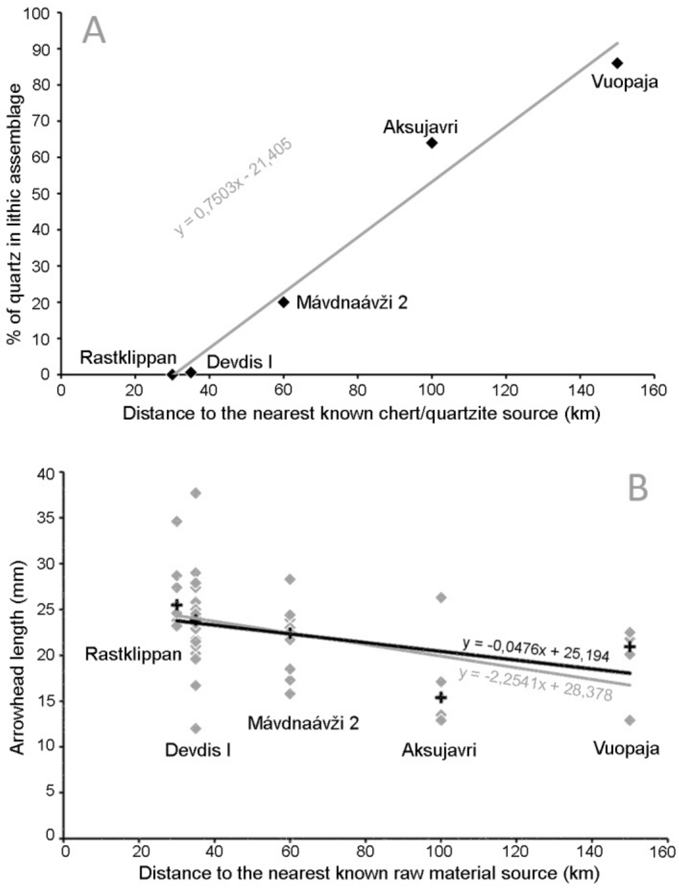


FIGURE 24. A) The relationship between the percentage of quartz in a site inventory and the distance to the closest known source of high-quality raw material (the correlation coefficient of the linear trendline r = 0.99). B) The lengths of arrowheads (gray diamonds) and the median lengths of arrowheads (black crosses) by site in relation to the distance to a known source of arrowhead raw material, with linear trendlines (lengths of arrowheads, r = -0.43; median lengths of arrowheads, r = -0.62). Only the arrowheads of raw materials from known source areas are included in the graph. Material from five inland sites (Paper V). Note that at Aksujavri, a geological formation with possible chert sources is also found closer to the site. However, the presence of chert in the formation has not been confirmed (Hood 1992: 96).

acquired from several sources and that it was possible for a group to use a variety of coastal raw materials during a single short occupation of a site located at a considerable distance from the coast. These patterns are consistent with the other results suggesting high residential long-distance mobility.

The studied material also reveals that in addition to the finished tools, which in most cases can be called microlithic in terms of size, lithic raw materials were often also carried along in small-sized packages, often in the form of flakes, and that during on-site activities and/or re-tooling, these raw materials were either turned into tools or used as cores for the production of smaller flakes (Paper V). The size-graded debitage analysis of quartz artefacts from the Mávdnaávži 2 site further suggests that in addition to raw materials of low and localised availability, the widely available vein quartz was also transported as flake blanks rather than as cores or raw material chunks (Paper II).

4.4. Technological organisation, mobility, and the properties of quartz

The way technology was organised at the Late Mesolithic margin-retouched point sites thus has some features that indicate conservation of high-quality raw material of restricted availability. At the same time, however, there are indications that the technology was designed to facilitate an efficient use of vein quartz (Paper V).

Because it is prone to fragmentation and commonly contains many internal flaws, quartz is a raw material that can be considered unfavourable for the execution of blank-production technologies that are demanding in terms of raw material controllability. However, our results indicate that the fragmentation typical of quartz flakes (Callahan *et al.* 1992; Huang & Knutsson 1995;

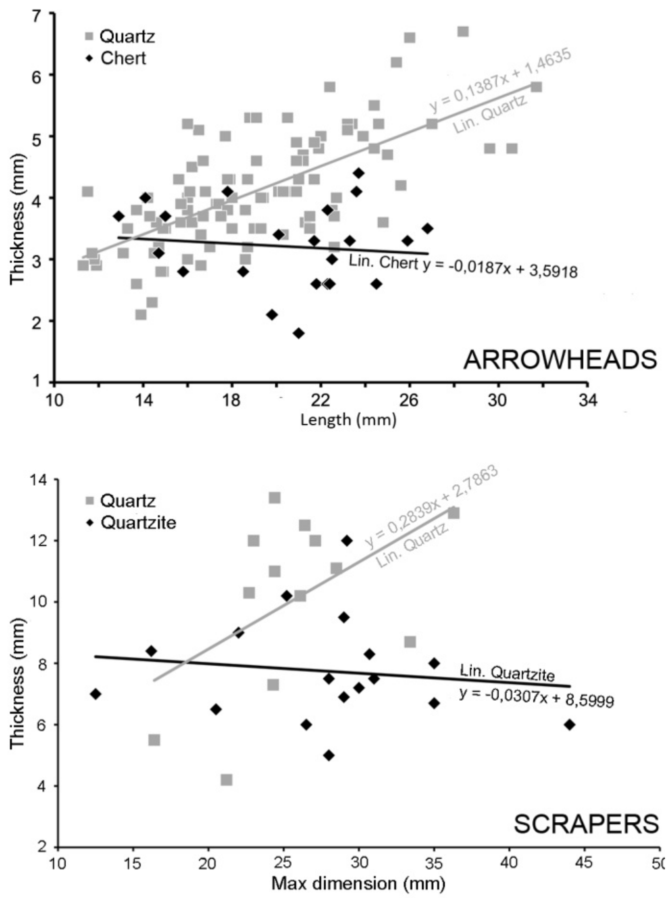


FIGURE 25. Thickness/length ratios of intact margin-retouched arrowheads and arrowheads with broken tips (1.5 mm added to length) made of quartz (n=98) and chert (n=22) studied in Paper IV (with linear trendlines). The relationship between scraper thickness and maximum outline dimension in quartz (n=13) and quartzite (n=17) scrapers studied in Paper V (with linear trendlines).

Knutsson 1998) can be reduced by producing relatively thicker platform flakes (Paper III) and the results of Callahan *et al.* (1992) indicate that flake fragmentation can be reduced by the use of bipolar-on-anvil reduction.

In fact, from the perspective of the issues discussed in this study, the most important results from the experimental research on the properties of vein quartz are related to the constraints the fragility of the raw material imposes on core reduction and the ways of minimising the fragmentation of quartz flakes in lithic production and use. The comparisons made in Papers IV and V between implements made of quartz and counterparts made of less fragile raw materials suggest that the production of relatively thicker flakes from quartz than from other, more resilient raw materials was common in the studied technology and that the fragility of quartz was compensated for by using design criteria that reduced the risk of failure. This is demonstrated by arrowheads made of vein quartz being thicker than ones made of chert and by the thickness of quartz points increasing with increasing length, while the thickness of chert points tends to remain the same irrespective of point length (Paper IV). The same principle of increasing thickness is also observed in quartz scrapers, in comparison to counterparts made of fine-grained quartzite (**Fig. 25**; Paper V).

Other features in the studied assemblages that can be readily interpreted as ways to reduce or cope with quartz fragmentation and/or the risk of raw material failure when using quartz are the selection and transportation of flakes (Papers II and V). A quartz core contains less usable tool edge than a comparable amount of raw material of better working qualities (Paper III), but this is not as much the case with flakes. The perpendicular orientation of quartz points with respect to the blank (Paper IV), the use of bipolar reduction specifically on quartz (Paper V), and when available, the preference for more resilient raw materials for the most critical tasks (Paper V) are also indicative of technological and organisational choices made to maximise the utility of the available raw materials, of which quartz comprised a major part, when moving over large stretches of land with very few areas where raw material of good workability could be found.

Flake-based production represents a marked informalisation of stone tool technology in the coastal area in comparison to the formal blade production known from the earlier phases (Hesjedal *et al.* 1996:186; Olsen 1994:34; Papers I, IV, and V), while in the inland region, despite being a simple artefact type, the oblique point is exceptionally formal in comparison to the simple informal tools found at Phase II sites. The results nonetheless suggest that in the context of Late Mesolithic margin-retouched points in northernmost Fennoscandia, the way technology was organised was not determined only on the basis of transport cost. Although the availability of raw materials of better workability than quartz was low and localised, the technology was not formal in the way that Andrefsky's (1994) results would lead one to expect. The fact that high residential mobility was linked to a technology that utilised small flake blanks and tools is probably partly explained by low carrying costs (*cf.* Kuhn 1994; Surovell 2009:142–150), but it seems likely that it was also determined by the good availability of the low-workability quartz in the area of Archaean and Palaeoproterozoic bedrock. The end of blade production on the Finnmark coast can therefore be linked to prolonged stays in the interior.

In addition to reducing carrying costs, flake-based technology enabled the use of practically the same lithic operational sequences, as well as the same hafting technology, regardless of the geological setting, when moving into the inland region, thus minimising the risk of ending up without suitable raw material (Paper V). The area between the Lake Inari region and the Finnmark coast is a case in point, as the area there with sources of chert and fine-grained quartzite is strictly restricted to the coastal strip. From an organisational point of view, the studied technology can therefore be seen as a solution where several organisational dimensions and design criteria intersect and that provided a tool kit well adapted to high residential mobility in the specific raw material setting. The organisational advantages of the technology include good durability and functional versatility, low carrying cost, and decreased raw material cost (Paper V). It can be concluded that the results of the analyses on settlement configuration and organisation of technology support the model presented in Paper II and speak in favour of a long-distance coast–inland residential mobility pattern in the main study area adjacent to the Barents Sea during Phase III (**Fig. 26**).

4.5. Why the high mobility?

The refuse faunas of the inland oblique point sites include European elk and reindeer (**Table 2**; Hood 2012; Paper I; V). According to vegetation reconstructions, at the time of their use, these sites would have been located in birch–pine or pine forest environments (Paper I). The Phase II to III changes in lithic technology thus seem to be connected to an organisational shift towards increased residential mobility of small groups within large ranges of land and hunting of large terrestrial mammals.

Among ethnographically documented hunter–gatherers, high mobility is usually linked to low utilisation of aquatic resources, whereas a decrease in effective temperature tends to result in

FIGURE 26. Variability in raw material use in the coast–inland long-distance residential mobility pattern with respect to the relative distance between the site and the coastal chert sources.

an increase in the average distance moved between residential locations, unless aquatic resources are heavily utilised or the resource base is exceptionally varied (Binford 2001; Blades 2001:9–10; Kelly 1995:120–131). It thus seems reasonable to look for evidence of a marked decrease in the Barents Sea aquatic resources, possibly linked to the 8.2 ka cold event, that could explain the development and continuation of the long-distance coast–inland mobility pattern.

4.5.1. The Barents Sea and early Holocene environmental change

The contemporary oceanographic conditions and the interrelated changes in the North Atlantic water circulation and climate during the early Holocene are central to the overall understanding of Mesolithic hunter–gatherer exploitation of Barents Sea aquatic resources. The surface waters of the Barents Sea were relatively warm during most of the period, while the salinity was lower than at present (**Fig**. **27D&E**). The Polar Front was located by the Finnmark coast (**Fig. 28)**, several hundreds of kilometres southwest of its present position, to where it moved approximately 7500 cal BP (5550 cal BC) (Risebrobakken *et al.* 2010). It is difficult to model the effects these conditions had on the marine ecosystem in comparison to the present situation, but it can be noted that in general, an increase in sea surface temperature has a positive effect on primary productivity (e.g., Sakshaug 1997), while a decrease in productivity eventually leads to lowered environmental carrying capacity, which in turn means lower human population density (Boone 2002; Kelly 1995; Riede 2009a).

It is generally accepted that most of the abrupt cold events that occurred during the Holocene, most notably the 8.2 ka event, were largely driven by

Lab. No.	**Site**	Dated sample	BP	**cal BP (2σ)**	cal BC (2σ)	**Refuse fauna**
Ua-40896	**Kaunisniemi 3**	Burnt bone, *Rangifer tarandus*	8004±46	**8899–8780**	7060–6710	***Rangifer tarandus***
Hel-2564	**Museotontti**	Charcoal	7750±120	**8587–8476**	7030–6410	***Rangifer tarandus***
Ua-40895	**Museotontti**	Burnt bone, *Rangifer tarandus*	7668±40	**8475–8412**	6590–6450	***Rangifer tarandus***
Tua-7194	**Aksujavri**	Burnt bone	6650±30	**7571–7507**	5631–5526	***Rangifer tarandus***
Ua-40900	**Mávdnaávži 2**	Charcoal, *Pinus sylvestris*	6580±38	**7502–7435**	5616–5478	***Rangifer tarandus***
Hela-963	**Mávdnaávži 2**	Burnt bone	6455±45	**7425–7327**	5484–5327	***Rangifer tarandus***
Ua-40897	**Vuopaja**	Burnt bone, *Rangifer tarandus*	6526±39	**7556–7329**	5607–5380	***Rangifer tarandus, Alces alces***

TABLE 2. Radiocarbon-dated refuse fauna found in association with margin-retouched points (Papers I and V). See Appendix I for references.

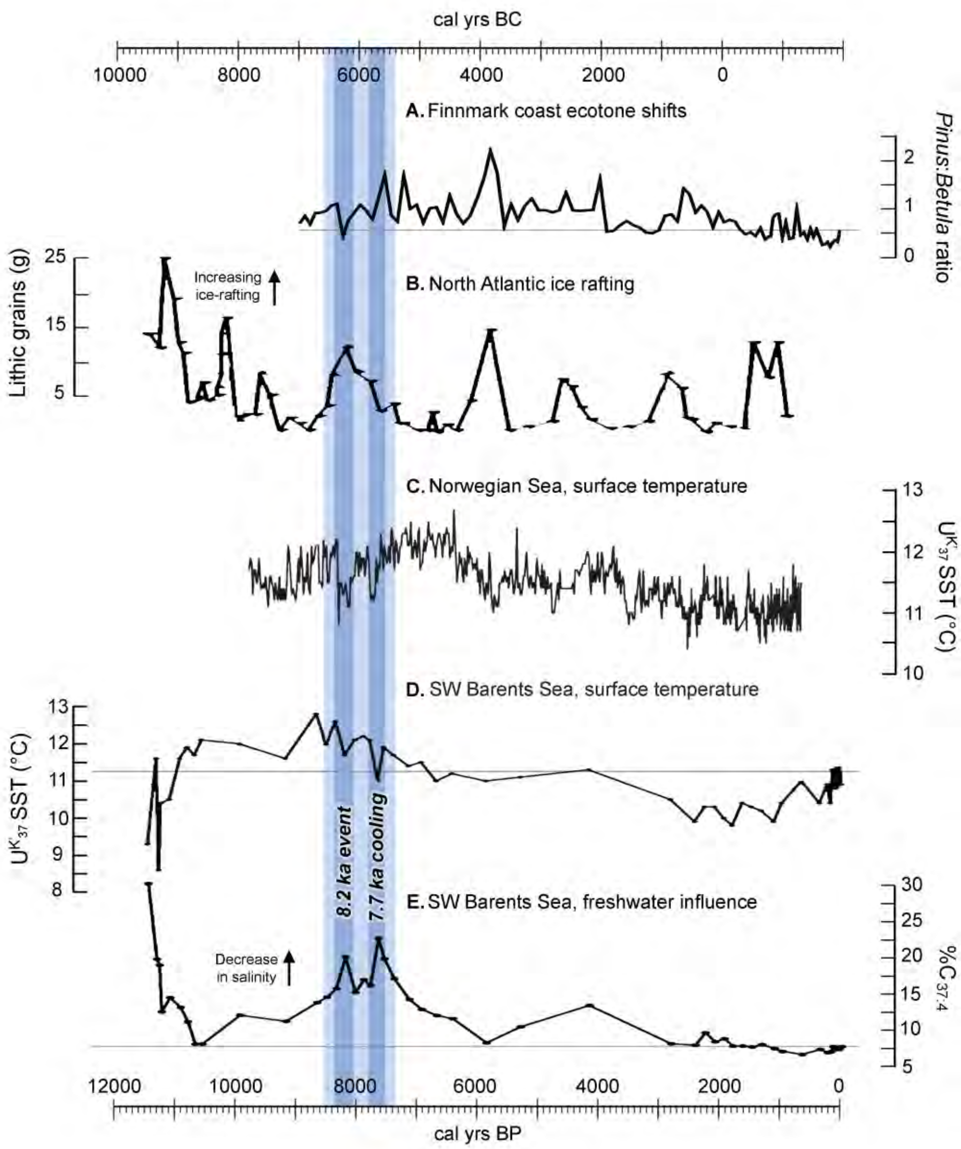


FIGURE 27. Reconstructions of Holocene coastal and marine conditions. A) Shifts in the pine–birch ecotone during the Holocene, as indicated by the *Pinus:Betula* pollen ratio in Nordkinnhalvøya, Finnmark (Allen *et al*. 2007); B) Amount of debris-bearing drift ice in the North Atlantic (Bond *et al*. 1997); C) Alkenone-derived high-resolution sea surface temperature reconstruction for the Norwegian Sea (Andersson *et al*. 2010; Calvo *et al*. 2002); D) Alkenone-derived sea surface summer temperatures for the southwestern Barents Sea (Chistyakova *et al*. 2010; Risebrobakken *et al*. 2010); E) Freshwater influence in the southwestern Barents Sea (Risebrobakken *et al*. 2010). The second vertical blue line indicates the *ca*. 7800–7500 cal BP cooling, while the grey horizontal lines indicate present conditions.

catastrophic outbursts of meltwater from pro-glacial lakes in North America. As noted earlier, the meltwater outbursts lowered North Atlantic sea surface temperatures and consequently affected the Atlantic Meridional Overturning Circulation by weakening the North Atlantic Thermohaline Circulation (Alley & Ágústsdóttir 2005; Daley *et al.* 2011; Delworth *et al.* 2008; Hoffman *et al.* 2012).

As a consequence of the outbursts, the flow of warm Atlantic waters in the Barents Sea also appears to have decreased, and accordingly, during the 8.2 ka event, for example, the salinity and the summer temperatures of the North Atlantic surface waters, as well as those of the Barents Sea, were reduced, the wintertime freezing of the Nordic Seas increased, and the sea ice cover in the North Atlantic expanded (**Fig. 27 & 28**; Alley & Ágústsdóttir 2005; Renssen *et al.* 2002; Risebrobakken *et al.* 2010). These developments are consistent with

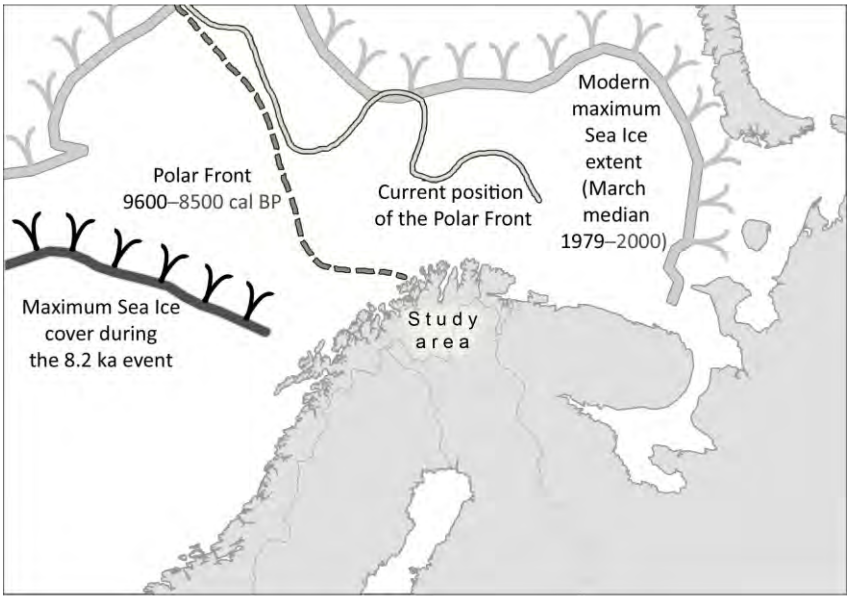


FIGURE 28. Modelled maximum extent of sea ice cover during the 8.2 event (Renssen *et al.* 2001) and the location of the Polar Front between 9600 and 8500 cal BP in comparison to the present seasonal maximum sea ice extent (March median 1979–2000; Polyak *et al.* 2010) and the current position of the Polar Front (*ca.* 7500 cal BP–present). Polar front locations according to Risebrobakken *et al.* (2010). Map by the author.

the expected effects of a weakening of the North Atlantic Thermohaline Circulation due to reduced salinity (Allen *et al.* 2007). For example, the annual duration of sea ice cover is estimated to have increased by approximately six months in the southeastern Barents Sea during the 8.2 ka event (Voronina *et al.* 2001).

In addition to the 8.2 ka event, several proxy records show a cold episode in the North Atlantic at *ca.* 7800–7500 cal BP (**Fig**. **27**; Aagaard-Sørensen *et al.* 2011), i.e., closely following the 8.2 ka event. This cooling episode is less well known than the preceding event and was most likely more local. However, both cold episodes coincided with periods of especially low solar radiative output (Vieira *et al.* 2011; Wanner *et al.* 2011), and a rapid climatic cooling coinciding with the latter episode is recorded in the combined mean July temperature reconstructions for northern Finnish Lapland (**Fig**. **12**; Erästö *et al. submitted*) as well as in a chironomid-based temperature reconstruction from Lake Sjuodjijaure in northern Sweden (Rosén *et al.* 2001). It is also worth noting that in regard to the 9300 cal BP cold event (*cf.* e.g., Yu *et al.* 2010), the Barents Sea marine proxies do not show any marked changes in salinity or surface temperature.

At present, physical conditions strongly determine the biological production processes of the Barents Sea, and climatic changes during modern times have led to significant fluctuations in the marine ecosystem, due to its sensitivity to temperature changes (Hjermann *et al.* 2004; Loeng & Drinkwater 2007). Primary productivity is highest in the area south of the Polar Front, where the warming influence of the Atlantic waters is more substantial and where the main part of the commercially exploited fish stocks are located, while productivity north of the Polar Front is markedly lower (Sakshaug 1997).

When sea ice cover in the Barents Sea increases, it initiates processes that result in food shortages throughout the ecosystem (Cochrane *et al.* 2009; Sakshaug 1997; Sakshaug & Slagstad 1992). In the years during which large amounts of warm Atlantic water flow into the Barents Sea, primary productivity can be 30% higher than the productivity in years with low Atlantic influx (Slagstad & Stokke 1994 in Sakshaug 1997). Moreover, interconnected developments, such as a crash in capelin population (Naustvoll & Kleiven 2009), a mass death of capelin-feeding sea birds, and a mass migration of harp seals southwards along the Norwegian coast (Sakshaug 1997) have been documented following years with low primary productivity.

Due to the difference in the location of the Polar Front, the generally lower salinity, and warmer surface waters, it is evident that the early Holocene ecosystem in the Barents Sea differed from the present situation, and therefore, it is not possible to draw direct analogies between the two. Nonetheless, temperature and solar radiation are considered to be the main factors limiting the productivity of ecosystems (e.g., Begon *et al.* 1996: 711–745), and it therefore also seems evident that the major coinciding changes in the physical conditions of the sea during the cold events mentioned, i.e., decreased surface temperatures, abrupt reductions in salinity, and increased ice cover, must have caused intense ecosystem responses following major decreases in primary productivity (see also Hood 1992b:77–79).

It is thus safe to say that the major cooling that lasted well over a hundred years, as well as the drop in solar radiation during both the 8.2 ka event and the cold episode that occurred *ca.* 7800–7500 cal BP, had severe if not disastrous consequences for the marine ecosystem in the Barents Sea and that there were also direct and severe food shortages higher up in the food web. It is reasonable to assume that such changes forced those hunter–gatherer groups that were heavily dependent on marine resources to reorganise their subsistence economy. In addition, the increases in the extent and duration of ice cover in the sea would have posed serious technological challenges to those hunters and fishers that were accustomed to open water.

4.6. Climate change and culture change–is there a connection?

The cold episodes and perturbations, especially in the marine ecosystem, that are likely to have followed from the changes detected in the environmental proxies provide a cogent reason for the reorganisation of land-use, technology, and mobility patterns indicated by the studied inland sites. Although the abrupt climatic cooling episodes most likely caused ecotone shifts and lower productivity and slowed the spread of pine forests in the variable forest/tundra environment of the inland region (Allen *et al.* 2007), the populations of reindeer and European elk, for example, can be expected to have recovered relatively quickly from the ecosystem changes, as they are cold-adapted species that respond negatively to increased ambient temperature (Chan *et al.* 2005; Tyler & Blix 1990; van Beest *et al.* 2012).

The reproductive success of these species seems to be more limited by the thickness of wintertime snow cover than by temperature because deep snow makes it more difficult for the animals to find food (Lee *et al.* 2000). Although the annual precipitation in the inland areas increased during the 8.2 ka event, according to the available proxy data, there are indications that in parts of the study area wintertime precipitation decreased (Allen *et al.* 2007). Hence, the physiological adaptations of northern ungulates to cold and the environmental variability within the study area together suggest that the reproductive success of these species would not necessarily have been seriously affected during periods of climatic cooling.

Although not discussed in detail in this dissertation, the importance of fish, birds, plants, and small mammals as food sources in addition to large mammals should not be underestimated. However, from the perspective of this study, the fact that the ecosystem changes were most likely more severe in the marine environment than in the terrestrial environment is more important than the actual composition of the food resource

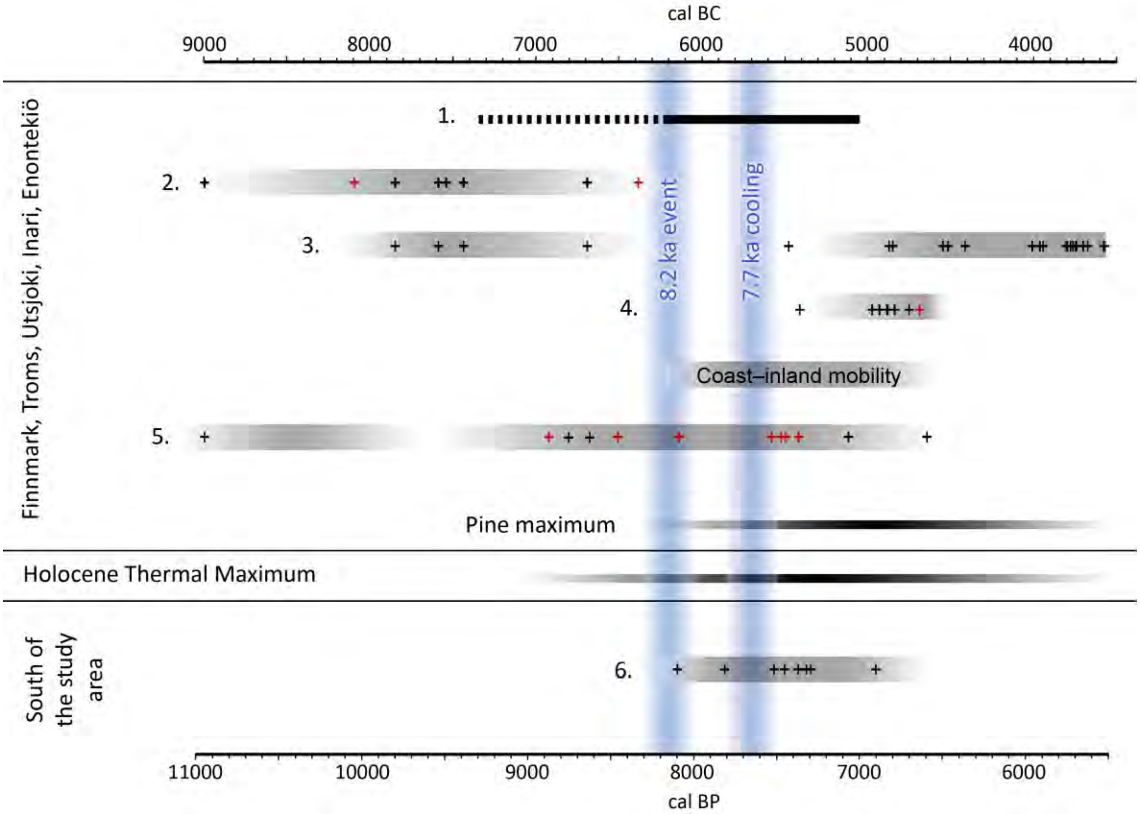


FIGURE 29. The suggested period of Late Mesolithic long-distance coast–inland residential mobility and a summary of the Holocene changes in material culture, settlement patterns, and natural environment discussed in the study, on the basis of shore displacement chronology and radiocarbon dates (14C median values marked with black (coast) and red (inland) crosses). 1. Quartz dominance on the Finnmark coast; 2. Use of formal blades in Finnmark and northernmost Finnish Lapland; 3. House-pits on the Finnmark coast; 4. Comb Ware pottery of the Säräisniemi 1 type in Finnmark and northernmost Finnish Lapland (the 14C dates are on food crust only); 5. Margin-retouched points in northernmost Finnish Lapland and Finnmark (four radiocarbon-dated contexts from Troms are included); 6. Margin-retouched points in the area south of 66°N. The use-period estimates (grey horizontal bars) are based on estimates by Grydeland (2000; 2005); Hesjedal *et al.* (1996; 2009); Olsen 1994; Schanche 1988; Woodman 1993; 1999; Paper V; see also chapter 4.6.2; and available radiocarbon dates (see Appendix II for dates and references). The durations of the HTM and the pine maximum are based on Kultti *et al.* (2006) and Figure 12). Note that the Storegga tsunami and the Tapes transgression most likely destroyed some coastal sites that predated the 8.2 ka event, and the latter phenomenon most likely also destroyed some of the then lowest-lying sites from the period between *ca.* 8500 and *ca.* 6500 cal BP (see Figure 21). However, the effects of these phenomena should have been least felt in eastern Finnmark (*cf.* Møller 1996; Romundset & Bondevik 2011) and it seems probable that pit-houses, for example, would not have been built close to the shoreline, and therefore, most would have been left unaffected by the tsunami and the rise in the sea level.

base, as it suggests that an increased importance of terrestrial resources can be expected at this point in time.

However, although the two successive marine cooling events that occurred *ca.* 8300–7500 cal BP offer a credible explanation for the organisational and technological changes observed in the archaeological material, i.e., the decrease in blade production and possibly pit-houses and the increase in quartz use on the Barents Sea coast, as well as the development of a coast–inland long-distance mobility pattern (**Fig. 29**), the temporal proximity of the changes does not provide direct evidence of causality (*cf.* Dincauze 2000; Eren 2012b; Robinson *et al.* 2013). In connection with the Younger Dryas climate change, Eren (2012b) suggests the examination of three key questions to make interpretations of climate-induced culture change more robust: whether there is good evidence of both environmental change and cultural change, whether there exists tight temporal co-variance between climate change and behavioural change, and whether there is evidence disproving other explanations for culture change. As the existence of both environmental and culture change during and after the 8.2 ka event has been demonstrated in the preceding chapters, it is appropriate to further scrutinise the data, especially in relation to the last two of these questions, to strengthen the case made in this study.

4.6.1. Temporal co-variance between climate change and behavioural change?

The time needed for the effects of an abrupt climatic change to become archaeologically observable is not easily determined and can be expected to be situational, as it is dependent on the time needed for demographic recuperation and economic reorganisation in any specific case. The time lag allowed when determining tight temporal co-variance is therefore a key question. As lowered carrying capacity due to abrupt climate change would be followed by an initially low population density and consequently reduced human activity (e.g., Riede 2009a), the odds of direct evidence of behavioural change being evident in the archaeological record without a time lag are small. This is especially true of areas with low archaeological research activity, such as northernmost Fennoscandia.

The analyses show changes in both material culture and larger-scale behavioural patterns, that is, technological organisation, settlement configuration, and land use. These changes, although related, are not necessarily synchronous. As mentioned earlier, the fact that some of the radiocarbon-dated margin-retouched point contexts predate the 8.2 ka event in the inland region suggests that such points were present there before the Barents Sea cooling and the changes that followed, according to the proxy records. This, however, is not surprising, as some use of the inland region by marine-adapted groups and interaction between inland and coastal groups during earlier phases of the Mesolithic seems unavoidable, despite the cultural border (Hood 1992b: 45, 85; Paper IV).

With respect to the effects of climatic cooling, however, more important than the earliest dates of points are the organisational changes indicated by the development of a new mobility pattern and the behavioural patterns indicated by the studied sites. The organisational and technological uniformity of these sites that postdate the successive cold episodes between *ca*. 8300 and *ca*. 7500 cal BP suggests that by *ca*. 7500 cal BP at the latest, a cultural and economic reorganisation had already taken place. At the same time, the dates of oblique point contexts in more southerly Finland suggest that the point-manufacturing concept started to spread south soon after the 8.2 ka event (Paper IV).

4.6.2. Other explanations for the changes in material culture?

It is well known that there is an endless supply of possible explanations for culture change, which in many cases are not independent of other variables and depend greatly on the theoretical orientation of the proponent. However, in the evolutionary and ecological framework adopted in this dissertation, the possibility that culture change was the result of gradual environmental and behavioural changes (*cf.* Eren 2012b; Jones 2009; Robinson *et al.* 2013) and the possibility of abrupt change caused by the Storegga tsunami stand out as obvious alternative explanations for the changes observed in material culture and subsistence strategy. In addition, as noted previously, a few explanations for the Late Mesolithic changes in the study area have been put forth in earlier research. I therefore concentrate on these explanations and alternatives and briefly address them in light of the results obtained in this study, as well as other, more recently published data.

Among the earlier explanations for changes in lithic technology and land use during the Late Mesolithic are the ideas that the margin-retouched point sites represent the first colonisation or at least the first permanent settling of inner Finnmark (Olsen 1994: 40, 45; Rankama 2003) and that the points appear in the area in tandem with the spread of pine forest (Olsen 1994: 39–41). However, recent archaeological and paleoecological studies have shown that the pioneer colonisation of the area took place prior to 9200 cal BP (*ca*. 7300 cal BC; Hood 2012), thus preceding the earliest known inland sites with margin-retouched points. In addition, the spread of pine forest began much earlier than was previously thought (Hood 2012; Jensen & Vorren 2008; Kultti *et al.* 2006; Paper I).

The idea that the decrease in blade production and the increased use of vein quartz at coastal sites was a consequence of quartz-adapted inland groups colonising the coastal sphere deserted by marine-adapted groups due to decreasing productivity (Rankama 2003; see also Hagen 2011) cannot be falsified with the present data. However, the increasing evidence of continuous margin-retouched point use in the coastal sphere makes it seem unlikely that the coastal groups would not have contributed to the development of the Phase III technology (Papers IV and V). Olsen's (1994:45) suggestion that the sites with margin-retouched points in the interior represent groups that left the coastal sphere due to social conflict is also difficult to falsify. However, no data supporting the suggestion of social conflict has so far been presented. Moreover, extensive social conflict, if it did indeed occur, was more probably a consequence of abrupt ecosystem turmoil and economic reorganisation than the actual reason for changes in land-use strategies (see chapter 1.5).

Grydeland (2005:71) also discusses scenarios of conflict and cooperation and suggests that the increase in quartz use in the Varangerfjord area towards the end of the Mesolithic was driven by a need for coastal hunter–gatherers to emphasise similarities and equivalence with the inlanders. Based on shore displacement chronology, Grydeland (2005) dates this change to the period after *ca*. 9350 cal BP (*ca*. 8300 BP or 7400 cal BC), and notes that at the same time, there also appears to have been a change towards a more sporadic use of coastal sites. Hagen (2011:74–77) links these changes to the 9300 cal BP cold event and suggests that quartz-adapted groups from the south settled in the area after the coastal population had weakened as a consequence of the cold event.

The possibility that the 9300 cal BP cold event, although not very marked in the marine proxies, had similar effects on the marine ecosystem in the easternmost part of the Finnmark coast, as I suggest the 8.2 ka event must have had on the whole of the Barents Sea coast, is intriguing. However, as is the case with the decrease in the number of house-pits (chapter 4.2), the shoreline dating of phenomena represented by sites at altitudes between approximately 37 and 25 metres above sea level at Varangerfjord is problematic, and the possibility that some of the changes observed by Grydeland in the Varanger area occurred considerably later cannot be ruled out. Nevertheless, regardless of whether the increase in quartz use and some other changes in the Varangerfjord area occurred after 9300 cal BP or during the transition from Phase II to Phase III, roughly coinciding with the 8.2 ka event, I suggest that the increase in quartz use is better explained by organisational changes and/or raw material availability than by cultural choices. The preference for chert and quartzite when available at the studied Late Mesolithic inland sites does not support the view that quartz was favoured for cultural reasons during the Late Mesolithic.

Although the possibility that the Late Mesolithic changes in the study area were driven by other and possibly gradual environmental or cultural changes cannot be totally excluded at the moment because of the inadequate temporal coverage and resolution of the existing data, there are no obvious aspects of the generally warming climate or the gradually expanding forest environment, for example, that would explain the shift away from marine resources. Although the succession of boreal forests in the inland region reached a climax at this point in time, alongside the pine maximum (Hood 2012; Kultti *et al.* 2006; Paper I), it does not seem likely that this development would have made the interior markedly more attractive for marine-adapted hunter–gatherers, unless there was a marked deterioration in marine productivity or an abrupt threshold-type change in the hunter–gatherer system, because stable old-growth boreal forests, although predictable in terms of patch composition, are relatively low in prey density (*cf.* Winterhalder 1981; 1983).

It is known that ecological systems are often nonlinear as well as dynamic and that even minor environmental change can cause an ecosystem to pass a threshold after which it may not be able to return to the preceding state (e.g., Burkett *et al.* 2005; Fagre *et al.* 2009). Treshold-type changes may result from climate change but also in response to other, even small, environmental changes that cause the exceeding of threshold values. Therefore, the possibility that a change other than the consequences of the climate event drove the system into an alternative stable state should also be kept in mind as a possible alternative when discussing the ecological and cultural changes in Late Mesolithic northern Fennoscandia. This type of alternative state could have been caused, for example, by the 8200 cal BP Storegga tsunami. As has been noted by Hagen (2011:67–70) in regard to coastal population size, the effects of the Storegga tsunami (Romundset & Bondevik 2011) would most likely have been similar in some ways to the expected effects of the 8.2 ka event. A population crash caused by the effects of the tsunami on the lowest-lying coastal sites can therefore explain some of the observed changes in the level of coastal activity. As noted before, a demographic collapse can also lead to a loss of technological knowledge, which could explain the major technological changes on the coast. However, the tsunami effects would not explain the development of a long-distance coast—inland residential mobility pattern combined with a low archaeological signal on the coast unless marine productivity also remained markedly low.

It therefore seems likely that the 8.2 ka event was the main driver of the sociocultural change since the current evidence suggests a gradual increase in coastal human activity after *ca*. 7800 cal BP or 5850 cal BC in the western part of the studied area and a few hundred years later in the eastern part (Hagen 2011:78), as well as a re-appearance of large coastal sites with pit-houses approximately 7000 cal BP, i.e., after the two successive marine cooling events but still during the Holocene Thermal and pine forest maxima. This suggests that the reason for the decrease in coastal activity during the Late Mesolithic was temporary and related to changes in the sea.

4.7. Technological traditions, cultural inertia, and environmental constraints

What, then, are the relationships between the Late Mesolithic change in technological and settlement organisation, the marine ecosystem changes most probably caused by the 8.2 ka event, and cultural evolution? When compared to what is known of the Mesolithic Phases I and II in the study area, in addition to a profound change in the way lithic technology was organised, the analysed Phase III sites and lithic artefacts seem to represent a change in the distribution of material culture traits, by which I mean the crossing of the cultural dividing border that may already have dveloped at the time of the pioneer colonisation of the area (chapter 5.1; Paper IV).

These types of long-standing borders between neighbouring groups or networks of groups, which are evident in the formation of differing material cultures and technologies, have been documented in many types of settings and by a variety of methods (e.g., Bergsvik 2011; Coia *et al.* 2012; Knutsson 2004; Knutsson & Knutsson 2012; Lemonnier 1986). The factors that slow down and guide the transmission of culture (and genes) between human populations include geomorphological barriers, linguistic differences, dominantly vertical modes of inheritance in small-scale traditional societies, and many types of social behaviour, such as rewarding of cooperation, punishing of defectors, territoriality, and suspicion towards outsiders, which cause and reinforce cultural diversity (Barbujani & Sokal 1990; Boyd & Richerson 2005: 133–251; Coia *et al.* 2012; Hewlett & Cavalli-Sforza 1986; Pagel & Mace 2004). Many of these factors are self-enforcing, a fact that can be considered a major reason for the cultural and linguistic diversity of our species.

However, human populations need to keep the size of the breeding population large enough to survive. This is achieved by maintaining a mating pool of adequate size that consistently provides suitable mates for group members that reach reproductive age (Wobst 1974). Because population density and mating distance are found to be inversely correlated (Hertell & Tallavaara 2011a:32; MacDonald & Hewlett 1999) a demographic collapse, especially when population size is initially small, can be easily envisioned as resulting in increased mobility, increased marriage across linguistic and geomorphological barriers, and increased horizontal transmission of cultural traits between neighbouring groups and ultimately to the merging of these groups (*cf.* Pagel & Mace 2004:276–277).

In addition to geomorphological boundaries, a factor that most likely reinforced the earlier cultural and possibly also linguistic divide by giving rise to territoriality (*cf.* Kelly 1995: 181–203) was the localised and most likely rich and mostly predictable aquatic resource base of the sea. If a reduction in productivity caused by the 8.2 ka event, especially in the marine environment, and a consequent decrease in population density is accepted as the most likely scenario, it is not farfetched to suggest that as a consequence of the long-distance coast–inland mobility pattern, or possibly even as a factor contributing to its development, there was increased interaction between the coastal and inland groups and more frequent acquisition of mates over the earlier cultural divide.

This scenario also explains why the point type was put into use not only in areas on both sides of the earlier coast–inland material culture divide but also in the rest of eastern Fennoscandia after the 8.2 ka event. The oblique point, which appears to continue the millennia-long coastal margin-retouched point tradition, was included in the technological repertoire of the emerging adaptation that utilised both the coastal and inland areas. The rapid spread of the concept over most of eastern Fennoscandia at this point in time, most likely in established hunter–gatherer networks, marks the disappearance or at least a weakening of the earlier material culture divide. Most probably the same networks had a major role in the introduction of Comb Ware pottery into northernmost Fennoscandia approximately 7000 cal BP (*ca*. 5000 cal BC) and slightly later in the distribution of amber, red slate, and copper in eastern and northern Fennoscandia (*cf.* Damm 2006).

A similar cultural divide also seems to have existed in northern Sweden, where the distribution of Late Mesolithic oblique points meets the distribution of contemporaneous handle cores (Paper I; chapter 4.1). Like the cultural border discussed above, this border coincides with a zone within which the Scandinavian Ice Sheet formed a barrier for post-glacial pioneer populations (*cf.* Knusson & Knutsson 2012) and thus seems to give archaeological support to the notion that history explains a significant fraction of material culture. Evolutionary forces, including selective behaviour, can only affect the frequencies of those variants that are present.

However, because it is clear that environmental constraints, marine cooling, and the properties of the available raw materials played major roles in the way the studied technology was organised, its development seems to be best explained by a combination of social, economic, and finally also technological reorganisation, that is, by history *and* environmental constraints.

5. CONCLUSIONS, LIMITATIONS, AND AVENUES FOR FUTURE RESEARCH

In this dissertation, I set out to study the relationship between the 8.2 ka climate event and the Late Mesolithic lithic technological changes technology in northernmost Fennoscandia. By presenting the first comprehensive survey of the date and extent of Late Mesolithic margin-retouched point use in Fennoscandia, by presenting new data from the inland areas of northernmost Fennoscandia, and by comparing the results of these segments of the study to archaeological and environmental data available from the Barents Sea coastal sphere, I have developed an internally coherent description of a scenario of environmental changes related to marine and climatic cooling as the drivers behind several organisational and cultural changes that took place in the northern and eastern Fennoscandian Late Mesolithic. In this final chapter, I summarise the main conclusions and briefly discuss the limitations of the results, as well as some topics for future research.

5.1. Conclusions

As Grydeland (2000; 2005) has noted, there are no reasons to suggest that the Mesolithic period on the Barents Sea coast was a time of constant population growth and environmental stability. On the contrary, the published proxies of climatic and marine conditions during the early Holocene show that there were severe fluctuations in the key variables that determine the productivity of the sea and thus directly affect the carrying capacity of the coastal environment. Between *ca*. 8300 and 7500 cal BP, there were two consecutive drops in salinity and temperature which most likely reflected a reduction in the influx of warm Atlantic waters into the Barents Sea. The first of these episodes was consistent with the widely felt 8.2 ka event, while the second cooling episode between *ca*. 7800 and 7500 cal BP was most likely more local but continued the period of low marine productivity.

In this dissertation, I show that these cooling episodes most likely caused major economic and technological reorganisation of human adaptations in the area. Although the changes in lithic technology known to have taken place during the Late Mesolithic in northernmost Fennoscandia were not necessarily synchronous and may therefore have resulted from differing processes, the new evidence presented in this study from Late Mesolithic inland sites and the large coast–inland-oriented foraging ranges suggested by this evidence are consistent with the expectation of a major reorganisation of land use and an increased utilisation of terrestrial resources as a consequence of decreased marine productivity.

The large coast–inland-oriented foraging ranges explain the way technology was organised at both the inland sites and coastal sites. The changes in settlement configuration brought about a clear change in the relationship between raw material availability and stone tool production, which explains why the importance of quartz as a raw material grew and why a variety of raw materials, including fine-grained chert and quartzite of the Barents Sea coast, as well as the low-workability quartzes of the interior, were used to produce margin-retouched points during the Late Mesolithic.

The new flake-based technology that developed was well adapted to high mobility within large territories that encompassed both the inland area, where only raw materials of low working quality were available, and the coast, with localised sources of more reliable and more workable raw materials, as it relaxed the need to restock with specific types of raw material.

At the same time, the margin-retouched points, now as a part of the mobile Late Mesolithic long-distance tool kit, seem to continue a technological tradition that can be traced back to the Upper Palaeolithic Ahrensburgian points of north central Europe. The technology thus shows that both cultural and environmental dimensions affected the design of tools and weapons. This means that other groups with different cultural backgrounds could very well have developed other technological solutions even in the same environmental circumstances. The Late Mesolithic handle-core-based technology that was used to produce bladelets from quartz but also from raw materials of better working quality in the area directly west of the region studied in this dissertation may therefore represent a different solution to the same set of problems.

The study also shows that the Late Mesolithic margin-retouched points in northern Fennoscandia are most likely related to their counterparts in more southerly parts of eastern Fennoscandia and that the transmission of the point concept to the south from the Barents Sea coastal sphere can also be linked to the changes caused by the 8.2 ka event, namely, increased mortality and demographic reorganisation in northernmost Fennoscandia. These changes led to the inclusion of the Finnmark coast in the hunter–gatherer network that covered most of eastern Fennoscandia and within which socially transmitted information, as well as exchanged goods, spread rapidly during subsequent periods.

5.2. Limitations

The primary limitation in the archaeological data used in the study is the still relatively low number of radiocarbon-dated contexts and studied sites in the area. This limitation raises the question of representativity and prevents a more secure chronological fixing of phenomena dated using shore displacement chronology or by a limited number of radiocarbon dates. Luckily, however, in regard to the dating of large-scale phenomena, in Fennoscandia, shore displacement chronology offers a complementary dating method that I have been able to use in this study alongside radiocarbon dates.

On the other hand, the representativeness of available data is a problem in all archaeological research, and this problem has to be accepted to be able to make inferences about cultural history and past human behaviour. Nevertheless, it should be kept in mind that the conclusions presented in the study are based on currently available evidence and that the way the study is constructed should make it possible to test the conclusions presented if and when new data become available.

The fact that the study was conducted from an "inland" perspective can also be taken as a limitation, although the results of the study offer new evidence that can be used to interpret coastal changes as well. The study approach also offers advantages in the form of unmixed sites with good preservation and a good perspective on the way raw material moved in the region. A more comprehensive survey of margin-retouched point sites and use on the Barents Sea coast and the inclusion of coastal sites in the analyses of raw material composition, site structure, and technology at Late Mesolithic sites, not to mention analyses of technological organisation at sites dating to the earlier Mesolithic phases, would obviously have made the study more robust. Such analyses, however, are not possible within the limits of a single dissertation. The available data from coastal sites seem nevertheless to be consistent with the data from the inland sites and will hopefully be supplemented in the future.

The study also leaves open the question of why the arrowhead concept was transmitted so quickly over such a wide geographical area. The small margin-retouched arrowheads of the Late Glacial Ahrensburgian reindeer hunters (Baales 1999; Riede 2009c), as well as studies on the penetrative and cutting qualities of oblique and transverse arrowheads (Brizzi *in press*; Friis-Hansen 1990; Seppä 1997), suggest that the Late Mesolithic points discussed in this dissertation were for the most part well fit for the hunting of relatively large game, including the northern ungulates that dominate the refuse fauna at the studied sites. The functional efficiency of the point concept can therefore be a major factor in the rapid adoption of the point type in the south. The fact that the assemblages include also points with a transverse edge and consequently considerably lower penetrative qualities, however, suggests that some of the variation in the Late Mesolithic points may relate to an increased importance of small game and possibly to changes in the productivity of the Baltic Sea (Brizzi *in press*; Paper IV).

Because there are no directly preceding projectile points in the archaeological record in the area of present-day Finland, the spread of the point concept could also reflect a re-introduction of bow-and-arrow technology (*cf.* Riede 2009c). However, this scenario would require first that bow-and-arrow technology was lost after the country was first colonised and second that it was not re-introduced during several millennia between the pioneer colonisation phase and the 8.2 ka event, even if it was known in nearby regions (see, e.g., Burov 1981; Gerasimov 2012; Tarasov *et al.* 2007 on the area to the east of Finland). It therefore seems more plausible that prior to the introduction of the margin-retouched point concept from the north, arrowheads were made from organic materials and/or unstandardised quartz fragments and that the new arrowhead concept had qualities (possibly the easy producibility, standardised form, and superior functional properties) that made its users more successful in some respect and therefore targets of imitation (*cf.* Boyd & Richerson 2005; Rogers & Shoemaker 1971).

5.3. Future research

Many of the limitations that prevent reaching an archaeologically more comprehensive picture of the phenomena studied in this dissertation can be reduced by conducting further studies and by increasing the available data. In addition, a fruitful avenue for future research would be to build and test more formal models of culture–environment dynamics in the study area. This type of research would contribute to a better understanding of the environmental constraints in the area, as well as their effects on the way humans adapted to changes in various environmental variables, as well as to demographic changes. Most importantly, this type of research would increase the understanding of culture-induced diversity in behavioural solutions.

Future research will hopefully also include more detailed study of prehistoric human behavioural adaptation to the 8.2 ka event and other periods of climatic turmoil in Fennoscandia. To gain a better understanding of the interrelated effects of changes in the North Atlantic oceanic patterns and the climate in northernmost Fennoscandia, it could be beneficial to further scrutinise potential changes in technology and behaviour in connection with other known abrupt climatic cold periods. These include, for example, the 9.3 ka event mentioned above that may have affected coastal groups on the Finnmark coast (Hagen 2011; Korhola *et al*. 2002) and the early Holocene 10.2 ka event (Seppä *et al*. 2002; see also Tallavaara *et al*. in press), which roughly coincides with the earliest radiocarbon-dated sites with post-Swiderian blade technology in eastern Finnmark.

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APPENDIX I. RADIOCARBON DATED MESOLTHIC UNGULATE BONE CONTEXTS IN FINNMARKSVIDDA,UTSJOKI,INARI, AND ENONTEKIÖ

Site	Context/area	Species	D/I	Dated sample	Lab. nr.	BP	calBC, 2σ	M cal BC	M cal BP	Reference
Virdnejávri 113	Bone "midden"	*Alces alces*	Indirect	Burnt bone	TUa-7193	8295 ± 35	7481 – 7191	7368	9317	Hood 2012
Lahdenperä 1		*Alces alces*	Direct	Burnt bone	Ua-41080	8024 ± 55	7081 – 6699	6934	8883	Pesonen *et al* . n.d.; Talavaara *et al* . in press
Virdnejávri 101	N-most pit	*Alces alces*	Indirect	Burnt bone	TUa-7192	7880 ± 35	7021 – 6638	6727	8676	Hood 2012
Saamen museo	A4A*	*Alces alces*	Indirect	Charcoal	Hel-3568	7330 ± 120	6430 – 6003	6200	8149	Rankama & Ukkonen 2001; Halinen 2005
Suonttajoki W1	A2, refuse pit	*Alces alces*	Indirect	Charcoal	Hel-3589	6940 ± 120	6029 – 5630	5832	7781	Rankama & Ukkonen 2001
Vuopaja N	A1, Pit*	*Alces alces*	Indirect	Charcoal	Hel-3569	6850 ± 110	5983 – 5564	5754	7703	Rankama & Ukkonen 2001; Halinen 2005
Virdnejávri 24	Burnt bone deposit	*Alces alces*	Indirect	Burnt bone	Beta-58655	5260 ± 250	4682 – 3535	4090	6039	Hood 2012; Simonsen 2001
Sujala	Area 2	*Rangifer tarandus*	Indirect	Burnt bone	Hela-1102	9265 ± 65	8695 – 8302	8492	10441	Rankama & Kankaanpää 2008
Sujala	Area 2	*Rangifer tarandus*	Indirect	Burnt bone	Hela-1442	9240 ± 60	8612 – 8305	8460	10409	Rankama & Kankaanpää 2008
Sujala	Area 2	*Rangifer tarandus*	Indirect	Burnt bone	Hela-1441	9140 ± 60	8541 – 8256	8367	10316	Rankama & Kankaanpää 2008
Sujala	Area 2	*Rangifer tarandus*	Indirect	Burnt bone	Hela-1103	8940 ± 80	8288 – 7826	8091	10040	Rankama & Kankaanpää 2008
Sujala	Area 2	*Rangifer tarandus*	Indirect	Burnt bone	Hela-1104	8930 ± 85	8287 – 7794	8079	10028	Rankama & Kankaanpää 2008
Virdnejávri 113	Bone "midden"	*Rangifer tarandus*	Indirect	Burnt bone	TUa-7193	8295 ± 35	7481 – 7191	7368	9317	Hood 2012
Kaunisniemi 3	Hearth	*Rangifer tarandus*	Direct	Burnt bone	Ua-40896	8004 ± 46	7063 – 6710	6924	8873	Paper IV
Virdnejávri 101	N-most pit	*Rangifer tarandus*	Indirect	Burnt bone	TUa-7192	7880 ± 35	7021 – 6638	6727	8676	Hood 2012
Museotontti	A11A, refuse pit	*Rangifer tarandus*	Indirect	Charcoal	Hel-2564	7750 ± 120	7029 – 6414	6610	8559	Halinen 2005
Museotontti	A11A, refuse pit*	*Rangifer tarandus*	Direct	Burnt bone	Ua-40895	7668 ± 40	6594 – 6449	6508	8457	Paper IV
Museotontti	A15, hearth*	*Rangifer tarandus*	Indirect	Charcoal	Hel-2728	7640 ± 120	6770 – 6232	6501	8450	Halinen 2005
Museotontti	A12, refuse pit*	*Rangifer tarandus*	Indirect	Charcoal	Hel-2565	7640 ± 110	6697 – 6238	6500	8449	Halinen 2005
Saamen museo	A31*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3580	7600 ± 90	6634 – 6254	6458	8407	Halinen 2005
Vuopaja N	A2*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3570	7530 ± 150	6677 – 6064	6385	8334	Halinen 2005
Suonttajoki W2	A1, refuse pit*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3209	7300 ± 110	6401 – 5990	6172	8121	Halinen 2005
Museotontti	A3, Hearth*	*Rangifer tarandus*	Indirect	Charcoal	Hel-2559	7210 ± 120	6368 – 5847	6092	8041	Halinen 2005
Buolžajávri Nord-3	Hearth	*Rangifer tarandus*	Direct	Burnt bone	TRa-3322	7180 ± 55	6212 – 5927	6048	7997	Hood 2012
Aittalahti	A5A, refuse pit*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3212	7060 ± 130	6215 – 5716	5933	7882	Halinen 2005
Suonttajoki W1	A2, refuse pit*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3589	6940 ± 120	6029 – 5630	5832	7781	Rankama & Ukkonen 2001
Saamen museo	A10, pit 1*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3123	6920 ± 130	6051 – 5617	5817	7766	Halinen 2005
Saamen museo	A10, pit 3*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3124	6870 ± 150	6030 – 5518	5778	7727	Halinen 2005
Vuopaja N	A1, Pit*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3569	6850 ± 110	5983 – 5564	5754	7703	Rankama & Ukkonen 2001; Halinen 2005
Saamen museo	A4B*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3315	6760 ± 150	5987 – 5469	5680	7629	Halinen 2005
Aksujavri	L4, Bone concentr.	*Rangifer tarandus*	Indirect	Burnt bone	Tua-7194	6650 ± 30	5631 – 5526	5582	7531	Hood 2012
Majava	Hearth	*Rangifer tarandus*	Indirect	Charcoal	Hel-3593	6570 ± 120	5712 – 5318	5521	7470	Halinen 2005
Mávdnaávži 2	Hearth/pit	*Rangifer tarandus*	Indirect	Charcoal	Ua-40900	6580 ± 38	5553 – 5486	5519	7468	Paper IV
Vuopaja	A1, bone pit*	*Rangifer tarandus*	Direct	Burnt bone	Ua-40897	6526 ± 39	5607 – 5380	5495	7444	Paper IV
Mávdnaávži 2	Hearth/pit	*Rangifer tarandus*	Indirect	Burnt bone	Hela-963	6455 ± 45	5484 – 5327	5418	7367	Paper IV
Myllyjärämä	Hearth	*Rangifer tarandus*	Indirect	Charcoal	Hel-2711	6380 ± 110	5554 – 5064	5355	7304	Rankama & Ukkonen 2001
Jeagelnjarga	Probable hearth	*Rangifer tarandus*	Indirect	Burnt bone	TRa-423	6345 ± 35	5465 – 5222	5329	7278	Hood 2012
Sahaniemi	Hearth	*Rangifer tarandus*	Indirect	Charcoal	Hel-3211	6200 ± 110	5462 – 4848	5144	7093	Halinen 2005
Saamen museo	A16*	*Rangifer tarandus*	Indirect	Charcoal	Hel-3318	6080 ± 110	5297 – 4729	5006	6955	Halinen 2005

D/I = direct date on bone/indirect date from the same context as the bone; M = radiocarbon date median value. In the case of contexts with several radiocarbon dates, the encircled date has been used in Figure 13. Contexts marked with * after Halinen (2005).

APPENDIX II. LIST OF RADIOCARBON DATES USED IN THE STUDY

	C/I	Lab. Nr.	BP	cal BP, 2σ	M cal BP	M cal BC	Reference
Sites with formal blades							
Slettnes VII (B)	C	CAMS-6752	9610 ± 80	11193 – 10724	10949	9000	Hesjedal *et al*. 1996
Sujala (bone)	I	Hela-1103	8940 ± 80	10237 – 9775	10040	8091	Rankama & Kankaanpä
Slettnes IVA F45	C	Beta-49008	8880 ± 100	10229 – 9635	9970	8021	Hesjedal *et al*. 1996
Starehnjunni	C	unpub.	*ca*. 8700 ± ?	9700 – 9550	*ca*. 9650	*ca*. 7680	Niemi in Hood 2012
Slettnes IVA F45	C	Beta-49007	8550 ± 100	9886 – 9304	9539	7590	Hesjedal *et al*. 1996
Mortensnes F2R10	C	T-6415	8500 ± 120	9883 – 9135	9492	7543	Schanche 1988
Stuorrasiida	C	Tua-3467	8365 ± 50	9490 – 9260	9388	7439	Grydeland 2005
Karlebotn	C	T-5428	7710 ± 480	9742 – 7612	8642	6693	Engelstad 1989
Vuopaja N	I	Hel-3570	7530 ± 150	8626 – 8013	8334	6385	Arponen & Hintikainen
House-pits							
Slettnes F45	C	Beta-49008	8880 ± 100	10229 – 9635	9970	8021	Hesjedal *et al*. 1996
Starehnjunni	C	unpub.	*ca*. 8700 ± ?	9700 – 9550	*ca*. 9650	*ca*. 7680	Niemi in Hood 2012
Slettnes F45	C	Beta-49007	8550 ± 100	9886 – 9304	9539	7590	Hesjedal *et al*. 1996
Stuorrasiida	C	Tua-3467	8365 ± 50	9490 – 9260	9388	7439	Grydeland 2005
Karlebotn	C	T-5428	7710 ± 480	9742 – 7612	8642	6693	Engelstad 1989
Sundfjæra Midtre, tuft 6	C	Combined[A]		7465 – 7333	7427	5478	
Sundfjæra Midtre, tuft 6	C	Wk-12029	6635 ± 57	7591 – 7430	7519	5570	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12034	6591 ± 38	7565 – 7430	7487	5538	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12031	6539 ± 40	7562 – 7334	7454	5505	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12030	6523 ± 49	7559 – 7322	7441	5492	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12035	6445 ± 45	7430 – 7275	7363	5414	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12033	6355 ± 37	7417 – 7175	7290	5341	Hesjedal *et al*. 2009
Slettnes VA, Hus A	C	Combined		6943 – 6695	6882	4873	
Slettnes VA, Hus A	C	Beta-52373	6000 ± 70	6990 – 6677	6842	4893	Hesjedal *et al*. 2009
Slettnes VA, Hus A	C	Beta-52374	6000 ± 60	7144 – 6667	6844	4895	Hesjedal *et al*. 2009
Slettnes VA, Hus A	C	Beta-49059	5730 ± 170	6956 – 6190	6547	4598	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12027	6016 ± 56	7005 – 6695	6859	4910	Hesjedal *et al*. 2009
Slettnes VB, F54	C	Beta-58664	6130 ± 120	7291 – 6726	7016	5067	Hesjedal *et al*. 2009
Slettnes VB, F54	C	Beta-58662	5810 ± 110	6893 – 6351	6616	4667	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12026	5800 ± 74	6779 – 6414	6600	4651	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12025	5628 ± 43	6491 – 6311	6406	4457	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 5	C	Combined[A]		6628 – 6411	6497	3798	
Sundfjæra Midtre, tuft 5	C	Wk-12037	5187 ± 69	6180 – 5750	5953	4004	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 5	C	Wk-12028	4998 ± 49	5893 – 5613	5733	3784	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 5	C	Wk-12044	4905 ± 58	5855 – 5484	5642	3693	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 10	C	Combined[A]		6628 – 6411	6497	4548	
Sundfjæra Midtre, tuft 10	C	Wk-12004	5896 ± 40	6831 – 6637	6716	4767	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 10	C	Wk-12003	5509 ± 41	6401 – 6215	6307	4358	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 8	C	Wk-12018	5684 ± 40	6629 – 6352	6466	4517	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 3	C	Combined		6440 – 6305	6364	4415	
Sundfjæra Midtre, tuft 3	C	Wk-12014	5646 ± 48	6535 – 6309	6427	4478	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 3	C	Wk-12011	5551 ± 45	6436 – 6281	6347	4398	Hesjedal *et al*. 2009
Slettnes IVB, F36	C	Combined[A]		5749 – 5332	5912	3963	
Slettnes IVB, F36	C	Beta-49013	5330 ± 130	6399 – 5762	6109	4160	Hesjedal *et al*. 2009
Slettnes IVB, F36	C	Beta-49014	5210 ± 60	6182 – 5769	5977	4028	Hesjedal *et al*. 2009
Slettnes IVB, F36	C	Beta-49009	4870 ± 100	5891 – 5326	5613	3664	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 2	C	Combined		6000 – 5910	5958	4009	
Sundfjæra Midtre, tuft 2	C	Wk-12001	5273 ± 67	6262 – 5915	6064	4115	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 2	C	Wk-11997	5279 ± 66	6263 – 5919	6069	4120	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 2	C	Wk-12000	5184 ± 83	6183 – 5745	5951	4002	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 2	C	Wk-11999	5168 ± 37	5996 – 5762	5928	3979	Hesjedal *et al*. 2009
Slettnes IVB,F41	C	Beta-49028	5140 ± 50	5991 – 5749	5893	3944	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 8	C	Wk-12016	5080 ± 50	5925 – 5665	5817	3868	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 6	C	Wk-12032	5064 ± 45	5915 – 5664	5815	3866	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 3	C	Wk-12008	5047 ± 43	5907 – 5663	5811	3862	Hesjedal *et al*. 2009
Slettnes VB, F67	C	Beta-49042	5000 ± 140	6175 – 5333	5754	3805	Hesjedal *et al*. 2009
Sundfjæra NV, tuft 13	C	Combined[A]		5892 – 5656	5747	3778	
Sundfjæra NV, tuft 13	C	Wk-11969	5207 ± 94	6261 – 5745	5983	4034	Hesjedal *et al*. 2009
Sundfjæra NV, tuft 13	C	Wk-11967	5012 ± 65	5905 – 5612	5757	3808	Hesjedal *et al*. 2009
Sundfjæra NV, tuft 13	C	Wk-11968	4759 ± 88	5650 – 5312	5488	3539	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 3	C	Wk-12009	5000 ± 64	5897 – 5610	5741	3792	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 4	C	Wk-12020	4964 ± 88	5911 – 5492	5713	3764	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 1	C	Wk-10738	4947 ± 86	5908 – 5485	5696	3747	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 9	C	Wk-11995	4919 ± 54	5858 – 5491	5692	3703	Hesjedal *et al*. 2009
Slettnes IVB,F39	C	Beta-49024	4940 ± 90	5906 – 5482	5691	3742	Hesjedal *et al*. 2009
Sundfjæra Midtre, tuft 8	C	Wk-12017	4910 ± 58	5861 – 5485	5646	3697	Hesjedal *et al*. 2009
Slettnes IVB,F37	C	Combined		5655 – 5332	5529	3580	
Slettnes IVB,F37	C	Beta-49017	4970 ± 110	5938 – 5473	5722	3773	Hesjedal *et al*. 2009
Slettnes IVB,F37	C	ETH-8897	4770 ± 60	5602 – 5325	5505	3556	Hesjedal *et al*. 2009
Advik, house f	C	T-197	4800 ± 150	5907 – 5062	5521	3572	Helskog 1980a
Slettnes IVB,F40	C	ETH-8898	4730 ± 60	5588 – 5321	5469	3520	Hesjedal *et al*. 2009
Slettnes IVB,F38	C	Beta-49021	4680 ± 90	5600 – 5062	5412	3463	Hesjedal *et al*. 2009

Säräisniemi 1 pottery							
Inganeset (Kjerringneset IV)	I	Tua-3025	5990 ± 55	6955 – 6676	6830	4881	Skandfer 2003
Lossoas hus	C	Tua-3024	6065 ± 55	7156 – 6757	6924	4975	Skandfer 2003
Mennikka (Skogfoss)	I	Tua-3022	5795 ± 55	6734 – 6469	6594	4645	Skandfer 2003
Mennikka (Skogfoss)	I	Tua-3027	5975 ± 60	6952 – 6669	6815	4866	Skandfer 2003
Noatun Innmarken	I	Tua-3023	6185 ± 65	7256 – 6932	7083	5134	Skandfer 2003
Noatun Innmarken	I	Tua-3029	5850 ± 55	6786 – 6503	6665	4716	Skandfer 2003
Noatun Neset	I	Beta-131296	5950 ± 90	7145 – 6547	6788	4839	Skandfer 2003
Noatun Neset Vest	I	Tua-3026	6030 ± 70	7156 – 6678	6880	4931	Skandfer 2003
Nordli	C	Tua-3028	6570 ± 60	7578 – 7333	7477	5528	Skandfer 2003
Nordli	C	Tua-3021	6330 ± 50	7415 – 7164	7262	5313	Skandfer 2003
Rönkönraivio	I	Hela-38	5830 ± 85	6854 – 6437	6637	4752	Carpelan 2004
MRP, north of 68°N							
Slettnes VII, Sjakt B		CAMS 6752	9610 ± 80	11193 – 10724	10949	9000	Hesjedal *et al*. 1996
Kaunisniemi 3		Ua-40896	8004 ± 46	9012 – 8659	8873	6924	Paper IV
Tönsnes 104380, Tuft 1		Combined		8973 – 8646	8756	6807	
Tönsnes 104380, Tuft 1		Wk-24651	7896 ± 30	8970 – 8596	8692	6743	Nilsen & Skandfer 2010
Tönsnes 104380, Tuft 1		Wk-24650	7913 ± 30	8975 – 8604	8721	6772	Nilsen & Skandfer 2010
Tönsnes 104380, Tuft 1		Wk-24636	7933 ± 30	8978 – 8637	8766	6817	Nilsen & Skandfer 2010
Tönsnes 104380, Tuft 1		Wk-24638	7898 ± 30	8971 – 8596	8695	6746	Nilsen & Skandfer 2010
Tönsnes 104380, Tuft 1		Wk-24637	7929 ± 30	8978 – 8635	8756	6807	Nilsen & Skandfer 2010
Tönsnes 104380, Tuft 1		Wk-24641	7962 ± 30	8990 – 8655	8849	6900	Nilsen & Skandfer 2010
Tönsnes 104380, Tuft 1		Wk-24642	7963 ± 30	8991 – 8656	8850	6901	Nilsen & Skandfer 2010
Tönsnes 104380, Tuft 1		Wk-24639	8001 ± 30	9006 – 8765	8880	6931	Nilsen & Skandfer 2010
Museotontti		Hel-2564	7750 ± 120	8587 – 8476	8559	6610	Halinen 2005
Tönsnes 104342		Combined[A]		8696 – 8593	8623	6674	Henriksen 2010
Tönsnes 104342		wk-24630	7928 ± 30	8978 – 8633	8754	6805	Henriksen 2010
Tönsnes 104342		wk-24631	7801 ± 30	8639 – 8483	8577	6628	Henriksen 2010
Tönsnes 104342		wk-24582	7796 ± 30	8637 – 8480	8573	6624	Henriksen 2010
Tönsnes 104342		wk-24583	7915 ± 30	8975 – 8605	8725	6776	Henriksen 2010
Tönsnes 104342		wk-24586	7868 ± 30	8772 – 8587	8643	6694	Henriksen 2010
Museotontti		Ua-40895	7668 ± 40	8475 – 8412	8458	6508	Paper IV
Jomppalanjärvi W		Ua-40899	7265 ± 40	8173 – 8003	8091	6142	Paper IV
Almenningen 1		Tua-3538	7260 ± 95	8316 – 7933	8087	6138	Blankholm 2008
Tönsnes 104380, Tuft 1		Wk-24635	7017 ± 30	7935 – 7790	7863	5914	Nilsen & Skandfer 2010
Aksujavri		Tua-7194	6650 ± 30	7571 – 7507	7531	5582	Hood 2012
Devdis I		T-1343	6575 ± 150	7708 – 7170	7471	5552	Helskog 1980b
Mavdnaavzi 2		Ua-40900	6580 ± 38	7502 – 7435	7478	5528	Paper IV
Vuopaja		Ua-40897	6526 ± 39	7556 – 7329	7444	5495	Paper IV
Mavdnaavzi 2		Hela-963	6455 ± 45	7425 – 7327	7367	5418	Paper IV
Slettnes VA:1		Combined[A]		7313 – 7018	7205	5068	
Slettnes VA:1		Beta-49052	6390 ± 80	7458 – 7163	7321	5372	Hesjedal *et al*. 1996
Slettnes VA:1		Beta-49057	6390 ± 100	7500 – 7027	7316	5367	Hesjedal *et al*. 1996
Slettnes VA:1		Beta-49056	6170 ± 170	7422 – 6676	7054	5105	Hesjedal *et al*. 1996
Slettnes VA:1		Beta-49053	5930 ± 110	7154 – 6480	6766	4817	Hesjedal *et al*. 1996
Mortensnes F8R12		T-6416	5770 ± 190	7156 – 6202	6594	4645	Schanche 1988
Slettnes VA:1		Beta-49054	5470 ± 120	6496 – 5945	6255	4306	Hesjedal *et al*. 1996
Tönsnes 104380, Tuft 1		Combined		6181 – 5995	6082	4133	
Tönsnes 104380, Tuft 1		Wk-24634	5306 ± 30	6185 – 5993	6084	4135	Nilsen & Skandfer 2010
Tönsnes 104380, Tuft 1		Wk-24643	5295 ± 30	6184 – 5954	6081	4132	Nilsen & Skandfer 2010
MRP, south of 66°N							
Lahdenkangas 1		Ua-40898	7284 ± 42	8177 – 8013	8098	6149	Paper IV
Rasi		Ua-40894	6981 ± 92	7976 – 7628	7813	5864	Paper IV
Kapatuosia		unpublished	6975 ± 75	7946 – 7675	7808	5859	MJRek
Arolammi 7D		GIN-11042	6630 ± 70	7617 – 7423	7516	5567	Matiskainen 2002
Muurahaisniemi		Hela-1947	6460 ± 45	7435 – 7275	7370	5421	Pers. comm. P. Pesonen
Rastklippan		Combined[B]		7427 – 7278	7361	5412	
Rastklippan		Ua-3656	6540 ± 75	7575 – 7312	7453	5504	Paper I
Rastklippan		Ua-3654	6410 ± 75	7432 – 7030	7339	5390	Paper I
Rastklippan		Ua-3655	6355 ± 75	7432 – 7030	7290	5341	Paper I
Hommas		Combined		7235 – 7020	7132	5268	
Hommas**		Hela-2054	6359 ± 39	7245 – 6990	7110	5161	Koivisto 2010
Hommas**		Hela-2051	6382 ± 41	7255 – 7005	7149	5200	Koivisto 2010
Hommas		Combined		7329 – 7102	7217	5183	
Hommas*		Hela-2052	6647 ± 41	7413 – 7109	7258	5309	Koivisto 2010
Hommas*		Hela-2053	6563 ± 41	7322 – 6975	7170	5221	Koivisto 2010
Arolammi 7D		GIN-11037	6050 ± 40	7137 6786	6902	4780	Matiskainen 2002

C/I = coast/inland, MRP = margin-retouched points, dates combined using the OxCal R_Combine function, A = X-Test fails at 5%. *Hela-2052 and Hela-2053 calibrated using Marine09 calibration curve (Reimer *et al*. 2009) with Delta_R LocalMarine -80 (Olsson 1980; Stuiver *et al*. 1986–2010). **Hela-2051 and Hela-2054 calibrated using a combination of corrected Marine09 (Delta_R LocalMarine -80) and IntCal 09 curves, with estimated 50% terrestrial and 50% marine diet. Atmospheric and marine data from Reimer *et al*. (2009). The circled dates are used in Figure 29.

APPENDIX III. SUMMARY OF PAPERS I–V

I Manninen, M. A. & Knutsson, K. 2011. Northern Inland Oblique Point Sites—a New Look into the Late Mesolithic Oblique Point Tradition in Eastern Fennoscandia. In: T. Rankama (Ed.), *Mesolithic Interfaces—Variability in Lithic Technologies in Eastern Fennoscandia*. Monographs of the Archaeological Society of Finland 1, 143–175.

The paper presents the first comprehensive survey of inland sites with margin-retouched points in northern Fennoscandia and their geographical and chronological distributions. A total of 31 sites from the counties of Norrbotten and Vasterbotten in Sweden, the counties of Finnmark and Troms in Norway, and the county of Lapland in Finland are described, and their relation to sites with margin-retouched points on the Barents Sea coast and more southerly Finland are discussed.

After a presentation and analysis of the available data, it is concluded that most reliable contexts with margin-retouched points at the northern inland sites are all dated to a short period *ca*. 7750–7050 cal BP (*ca*. 5800–5100 cal BC), while a clear majority of points appears to date to *ca*. 8450–6650 cal BP (*ca*. 6500−4700 cal BC), thus confirming the notion that margin-retouched points in the inland areas of northern Fennoscandia are a predominantly Late Mesolithic phenomenon.

Analyses of the arrowheads from the studied sites suggest that flake blanks from platform cores were used in point manufacture. This makes the mode of blank production a common denominator between these points, Phase III points in Barents Sea coastal sites (Hesjedal *et al.* 1996:186; Olsen 1994:34), and oblique points in more southerly Finland (Matiskainen 1986; Pesonen & Tallavaara 2006; Paper IV), while it differentiates these points from the Phase I margin-retouched points of northernmost Norway which were usually produced from blades (Hesjedal *et al.* 1996:166; Woodman 1999:301–302). The shapes of both the early and late margin-retouched points were also found to vary considerably. The results nevertheless indicate that oblique and transverse-edged points are more common than single-edged or double-edged tanged points among the Late Mesolithic coastal and inland points, while the contrary is true for the coastal Phase I points.

We also conclude that the flake blanks used in the production of Late Mesolithic margin-retouched points were not of a standardised shape and that the manufacture of points was not dependent on specific raw materials, although chert and fine-grained quartzite were preferred when available. The studied assemblages include points made of quartz, quartz crystal, slate, rhyolite and different types of chert and quartzite. It is also noted that this type of technology enables organisational strategies not tied to specific lithic raw material sources and facilitates movement in regions where access to raw materials differs from area to area.

The dating of the inland sites with margin-retouched points is also compared with the results of recent paleoecological studies conducted in the area. The comparison indicates that the sites were located in a boreal climax forest environment. This knowledge, together with an evaluation of available radiocarbon dates from surrounding areas, contradicts the earlier explanation (Olsen 1994:39–41) that the spread of oblique point technology in the inland areas of northern Norway was linked to a colonisation of previously inhabited areas and related to the spread of the boreal forest.

It is also suggested in the paper that the discussed arrowheads belong to a technological tradition that expanded rapidly over the whole of eastern and northern Fennoscandia during the Late Mesolithic through an interconnected network of hunter–gatherer groups. In addition to similar points and technology being used at the sites, the radiocarbon date spans for Late Mesolithic margin-retouched points at the northern inland sites (*ca*. 8450–6650 cal BP or 6500−4700 cal BC), on the Finnmark coast (*ca*. 7450–6250 cal BP or 5500–4300 cal BC) and in southern Finland (*ca*. 7450–6850 cal BP or 5500–4900 cal BC) are roughly the same.

A comparison between the distribution of Late Mesolithic margin-retouched points and the contemporaneous but more westerly distribution of handle cores (Olofsson 1995; 2003) is also made in the paper. The distributions of these two artefact types were found to be spatially exclusive. Based on this result, it is suggested that handle cores and the Late Mesolithic margin-retouched points are artefact types that represent contemporaneous but spatially exclusive social networks. It is further suggested that because the contact zone between these networks is in the area where the last remnants of the Scandinavian ice sheet melted at the end of the last glacial cycle, the border could reflect a historical border derived from the time when the first colonisers arriving from the south and those arriving from the east met in northern Sweden in the early Holocene.

The paper also provides a graph showing the shore displacement dates of margin-retouched point sites in relation to all sites on the southern shore of Varangerfjord (eastern Finnmark). Based on the graph, it is suggested that erosion and a packing of sites to certain altitudes caused by the mid-Holocene Tapes transgression were most likely the major factors contributing to what appears to be an absence of margin-retouched points in the archaeological record during Phase II and the beginning of Phase III, because during the Mesolithic as a whole, the number of coastal sites with margin-retouched points seems to correlate with the overall number of sites in the studied part of the coast and because there is a relatively high number of sites above the altitude corresponding to the transgressive phase.

II

Manninen, M. A. 2009. Evidence of mobility between the coast and the inland region in the Mesolithic of Northern Fennoscandia. In: S. B. McCartan, R. Schulting, G. Warren & P. Woodman (Eds.), *Mesolithic Horizons*, Vol. I. Oxbow books, Oxford, 102–108.

In this paper, I present a mobility model based on evidence from the Mávdnaávži 2 site in northernmost Finnish Lapland and a group of oblique points made of coastal cherts from the Lake Inari region, some 150 km from the Barents Sea coast. I use Minimum Analytical Nodule analysis to study future activity planning and the relative length of occupation at Mávdnaávži 2. Raw material composition and use indicate that the site was a single-occupation hunting camp used by a group that had utilised the Barents Sea coastal area at some point in their seasonal round. Using these results and an interpretation of earlier finds from the Lake Inari area, I propose a model of coast–inland mobility and that the coastal raw materials in the Lake Inari region were brought to the area as parts of mobile tool kits.

The mobility model predicts what types of Late Mesolithic assemblages should be found in and between the Barents Sea coast and the Lake Inari area, that is, a decreasing proportion of coastal raw materials and an increasing use of quartz with increasing distance from the coastal sources of raw materials and an almost exclusive use of quartz while moving gradually back towards the coastal area.

The paper includes a comparison between the size distribution of quartz artefacts at the Mávdnaávži 2 site and a nearby quartz knapping floor (Leakša-goađejohka 3, Manninen 2003). The result of the comparison suggests that flakes were brought to the Mávdnaávži 2 site for use as scraper blanks.

III

Tallavaara, M., Manninen, M. A., Hertell, E. & Rankama, T. 2010. How flakes shatter: a critical evaluation of quartz fracture analysis. *Journal of Archaeological Science* 37, 2442–2448.

The paper presents an experimental study of quartz flake fragmentation in which the inherent tendency of quartz flakes to shatter during detachment is scrutinised by studying statistically the effects of individual knapping style, indenter hardness, and relative thickness of flakes (thickness/length) as possible sources of variation in quartz flake fragmentation patterns. The study builds on and evaluates earlier results by Callahan *et al.* (1992), who found that quartz flake fragmentation is not random but rather clearly patterned and follows the rules of material science. In addition, the paper discusses the possible effects of flake fragmentation on the technological organisation of prehistoric quartz users.

The study demonstrates that quartz reduction does not always produce similar fragment distributions, even if the flaking method is controlled, and shows that differing fragment and fracture types are typical for detachments produced with hard and soft indenters. The results also suggest that the relative thickness of a flake has an effect on fragmentation. Increasing relative thickness increases the probability of a flake staying intact and decreases the probability of radial and particularly bending fractures.

Together with the results obtained by Callahan *et al.* (1992), our results suggest that quartz users most likely reduced fragmentation by producing thicker flakes or by using bipolar flaking. This conclusion is supported by studies in which artefacts made of quartz have been compared with artefacts made of more resilient raw materials. We further suggest that the production of thicker flakes has enhanced the durability of tools made of the fragile raw material because thicker tools are more resistant to breakage.

We conclude that if predictability in the technological process were desired, quartz must have been a problematic raw material for prehistoric knappers in many respects. For example, a quartz core contains more waste than, e.g., a chert core of equal size, due to its fragmentation tendency, the probable attempts to reduce it by producing thicker flakes, and the poor durability of quartz tools. A quartz core thus contains less usable tool edge than a comparable amount of a better raw material. This means that quartz would not be a desirable raw material especially when transportation costs are of importance.

IV

Manninen, M. A. & Tallavaara, M. 2011. Descent History of Mesolithic Oblique Points in Eastern Fennoscandia – a Technological Comparison Between Two Artefact Populations. In: T. Rankama (Ed.), *Mesolithic Interfaces – Variability in Lithic Technologies in Eastern Fennoscandia*. Monographs of the Archaeological Society of Finland 1, 177–211.

This paper discusses scenarios explaining how the margin-retouched point concept spread in Fennoscandia during the Late Mesolithic and the descent history of the arrowhead concept in Finland. We analyse a sample of 158 points from two geographically separate areas to determine whether they represent the same technological tradition with a common descent history or separate developments with a possible common distant ancestry.

The paper draws on radiocarbon dates and on a technological analysis designed to gather information on point shape and the manufacturing process. Measurable characteristics of point shape and the manufacturing process are compared statistically by geographic source area (i.e., northern Finnish Lapland or more southerly Finland) and by raw material.

The starting point in the paper is the conception, derived from cultural transmission theory, that because in Finland the margin-retouched point concept spread to areas in which directly preceding lithic arrowhead types were not known, differences or similarities in within-population variation could shed light on the transmission mechanisms behind the spread of the manufacturing concept and, consequently on the descent history of oblique points. However, because we presume that human behaviour is always a result of both cultural and environmental factors, we also study how much of the observed variation can be explained by environmental constraints, namely differing degrees of raw material availability and differing raw material properties.

The results of the technological analysis indicate that all of the points in both groups were made using flake blanks produced with platform reduction. Quartz was found to have been used to produce the majority of the points in the southern group, whereas chert was the most common raw material in the north. The variables initially considered as possibly reflecting differences in overall arrow technology (point weight, basal thickness, and basal width) exhibited only small differences between the point populations. The clearest differences are seen in the raw materials used, the points' orientations in relation to the blank, and the points' thicknesses and weights. In addition, the northern points are more heterogeneous as a group.

The effect of raw material is studied in the paper by dividing the point data by the raw material, and especially by contrasting the quartz point data from the two geographical groups with the chert point data. The results show that the thickness of quartz points increases with their length, which makes the quartz points thicker as a group, and that quartz points are oriented perpendicularly in relation to the blank regardless of the area of origin, whereas chert points are oriented parallel to the longitudinal axis of the flake as often as they are oriented perpendicularly to the axis.

The possible effects of different transmission mechanisms *versus* the effects of raw materials on the within-group variation are evaluated by studying correlation amongst variables in the different groups. The results of this analysis show that more significant correlation exists amongst the variables in the quartz points than amongst those in the southern group of points. It is therefore concluded that differences in raw material composition and properties explain most of the intergroup differences observed in the point data. The properties of quartz (fragility and proneness to fragmentation) reduced the degree of variation in the southern group and forced a more standardised and robust point shape in comparison with chert. Therefore, the differences in the degree of variation between points from the two geographical areas cannot be attributed directly to differing transmission mechanisms. The results suggest that the same technology was used to produce points in southern and northern Finland.

Based on the conclusion that all the studied points represent the same technological tradition, we study the spread of the margin-retouched point concept using radiocarbon dates. The results show that radiocarbon dates from oblique point contexts are consistent with the shore displacement dates of the point type in Finland and indicate that the point concept was present in northern Finland possibly as early as *ca*. 8850 cal BP (*ca*. 6900 cal BC), while the earliest contexts in southern Finland, according to shore displacement chronology and radiocarbon dating, are not earlier than *ca*. 8050 cal BP (*ca*. 6100 cal BC). We therefore suggest that in Finland, the concept spread from the north towards the south and that it most likely originated in a millennia-long tradition of producing margin-retouched points known from the Mesolithic of the Norwegian Barents Sea coast.

Lastly, we discuss the possibility that the spread of the point concept in Finland during the Late Mesolithic was related to climatic changes, that is, to the 8.2 ka event and the Holocene Thermal Maximum. We suggest that the environmental crisis caused by the 8.2 ka event in northernmost Fennoscandia led to social and economic reorganisation and to increased inter-group contact and cultural transmission between historically distinct populations descending from colonisation waves that originally spread to the area from west and southeast of the Scandinavian Ice Sheet. After the point concept was adopted by the "southern" population, the gradually warming climate after the event and the associated population growth, especially in the more southern parts of Finland, could then have caused the technology to be rapidly transmitted southwards.

V Manninen, M. A. & Knutsson, K. 2014. Lithic raw material diversification as an adaptive strategy—Technology, mobility, and site structure in Late Mesolithic northernmost Europe. *Journal of Anthropological Archaeology* 33, 84–98.

In this paper, we study the relationship between the organisation of stone tool production technology and settlement configuration, using assemblages from five practically contemporaneous (*ca*. 7650–7050 cal BP or 5700–5100 cal BC) inland sites with margin-retouched points. In addition to studying the site structure and technological organisation at these sites, we test the premise that high residential mobility and a low availability of tool stone with good working qualities leads to economising, especially intensification and formalisation. We first examine the degree of residential mobility from site structure, using behavioural inferences drawn from ethnographic and ethnoarchaeological research, and we then employ Minimum Analytical Nodule analysis to gain an understanding of raw material composition, use, and movement and their relation to raw material abundance and properties.

The results indicate that the sites represent short occupation spans and groups with high residential mobility. We find evidence for this from site structure as well as from the organisation of lithic technology. The results also show that the proportion of quartz in the site assemblages increases linearly with increasing distance to the closest known source of fine-grained raw material. In addition, there is an inverse correlation between arrowhead length and the distance to the closest known raw material source, suggesting intensification of raw material use with increasing distance to the source. The technology used to produce the lithic assemblages is nevertheless informal in most aspects, which means that in this case, there is no clear correlation between a low availability of raw material of good workability and a primarily formal lithic inventory. We also lack evidence of intensified use of tools and bipolar-on-anvil exhaustion of cores made of low-abundance raw materials, i.e., patterns that could indicate a maximisation of non-local raw material.

However, we find evidence that even if the localised raw materials of better workability were preferred when available, at sites located far from sources of such raw materials, the undesired properties of quartz were compensated for by favourable technological choices (producing relatively thicker platform flakes from quartz, using bipolar reduction on quartz, and using flake blanks in a way that reduced the risk of failure).

We conclude that restricted availability of high-quality raw material, due for instance to increased mobility or changes in the size or location of the foraging range, does not necessarily lead to formalisation and intensification but can in certain situations, as in the studied case, lead to the application of an adaptive strategy that can be called raw material diversification. This strategy can be regarded as a type of asset allocation in which investments are distributed to reduce risk in the event of a decline in a particular part of the investment portfolio. We suggest that the strategy entails a widening of the actively used raw material repertoire to include raw materials of relatively lower workability and a consequent alteration, often in the form of simplification and informalisation, of existing technological concepts. Consequently, we suggest that the flake-based technology used at the studied sites is a solution that continues to culturally reproduce the millennia-long margin-retouched point tradition while balancing organisational dimensions that increase the utility of quartz and those that maximise the utility of the intermittently available raw materials of better flakeability and controllability.